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WATER COMMITTEE.

REPORT

ON A

PUBLIC WATER SUPPLY

FOR

THE CITY OF MEMPHIS.

FEBRUARY 23, 1886.

MEMPHIS:
S. C. Toof & Co., Printers and Lithographers.
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MEMPHIS WATER COMMITTEE.

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R. W. MITCHELL.

Officers of the Taxing District—Members, ex-officio.

D. P. HADDEN, PRESIDENT,

S. P. WALKER, ATTORNEY,

NILES MERRIWETHER, ENGINEER.

CHAS. L. PULLEN, SECRETARY OF THE COMMITTEE.

REPORT.

MEMPHIS, February 23, 1886.

To the Water Committee.

GENTLEMEN: In pursuance of a resolution, passed by your Committee, August 7, 1885, leave is asked to submit a report of the results of the investigations and examinations which have been made respecting a water supply and a system of water works, adapted to the needs and means of Memphis. In submitting this report, it is the wish of the writer that it shall be received simply as a contribution from one member of the Committee, who has thought it to be his duty to perform a part of the work which was voluntarily undertaken by us, and that it is not, in any sense, intended as conclusive of the subject with which we are charged.

The question for our consideration is, First: To determine the debt, which Memphis as a city, is able to assume for obtaining a sufficient supply of satisfactory water; and for building permanent water works, so planned that the supply will be continuous, and the works capable of enlargement in the ratio of increasing population and area, and so adjusted from an economic point, that the revenue to be derived shall be adequate, not only to meet the fixed charges and cost of maintenance of the structures, but yield an annual surplus for improving them, until the city shall have reached a population that will enable it to make such additions to the original plant as will then meet its necessities. Second: To determine upon an

engineering plan, or plans, any one of which may be successfully carried out, within the limits of the conditions imposed by the aforementioned restrictions.

For determining approximately the debt which the city could float on a self-sustaining system, a careful analytical and comparative study was made of the plans and experience of other cities, whose geographical and topographical situation as it related to their sources of water supply, was similar to our own, taking in view the experience of the cities of the country generally. Respecting the most improved methods of pumping by steam and the construction of water works and their cost, the advice and counsel of experienced civil and mechanical engineers, manufacturers and contractors was obtained; the structures of other cities examined, and such reconnoissances made in and near Memphis, as were pertinent and necessary. These sides of the question considered, there remained for investigation the most important factor of the problem, the source of supply—a wholesome and abundant source, that would meet the wants and reasonable requirements of the public, from which water could be taken to cost no more than we are able to pay for, as formulated in the first premise, by means which should be practicable and permanent, as an engineering plan.

These investigations were conducted on the hypothesis that any plan which might be recommended by the Committee would be adopted and carried out by the city, and the works be owned and operated by it. A water works corporation composed of shareholders, however honorably managed, is, by the nature of its organization, devoted to private gain, and for that reason antagonizes the public interest wherever that interest is concerned. Moreover, its franchises and tenure are limited, and its management is

exposed to such factional disturbances as to obstruct the corporation from projecting and executing the necessary plans and improvements that may be required to meet the growing wants of a city yearly increasing in population. In a word, it is believed that a system of public water supply should be owned and operated by the city, for the sole benefit of its inhabitants.

The members of this Committee are too familiar with the history of the public debt of Memphis, lately wisely and skilfully adjusted by the authorities of the Taxing District, to recommend any proposition leading to the creation of a new debt, without mature deliberation. Since any system of water works, adequate to the necessities of the city, can be devised only by creating a debt, it ought to be demonstrated that the public burden will not be increased thereby; which is the same as to say that the works shall be maintained without the aid of taxation, more than the water rate paid to the present water company.

It will be found that our ability to maintain a water debt is not jeopardised by the uncertainties that attend new enterprises, because the experience of the Memphis Water Company enables us to forecast the revenue that will arise from a given investment. In the early stages of the history of water works, water is used by so small a proportion of the inhabitants of a city as to expose the venture to failure, or to require public aid for its success. We have passed this experimental period. The daily consumption of water has already reached 6,000,000 gallons, and its increasing use is assured by force of the law making sewer service compulsory. The number of miles of piping of our sewer system has doubled since the completion of the work in 1881, and is extending yearly. By

reference to the instructive tables (No 1 of the Appendix) prepared by Mr. Anthony Ross, of the Taxing District Engineers' Department, it will be seen by computation, that the unsewered parts of the city will require an additional supply of 837,200 gallons per day, and the adjacent suburbs 2,232,000 gallons. If we add to the compulsory supply the quantity that will be consumed by reason of increasing population, the improvement in the quality of the water, and the necessity for its use that will be felt and understood, every element of doubt of the financial success of the project would appear to be eliminated from it. Although there are no official data from which the ratio of increase of population can be determined, considering the obvious indications of prosperity, as illustrated in the construction of dwelling and business houses, the erection of manufacturing establishments, the opening of new railway lines, creating avenues of industry hitherto unknown to us, it would seem to be unwise to project any plan for a population less than 75,000, which aggregate will be probably reached in the period necessary for the completion of permanent works. The experience of other cities, whose conditions resemble our own, offers a field of study in which valuable information may be gathered to help us to a solution of the question. If, as a community, we are to achieve the great destiny we are now predicting for ourselves, there should be no hesitation on our part in attempting to accomplish in so vital a matter as our water supply, what our sister cities have demonstrated to be practicable. An examination of their methods and the burdens they entail, as bearing on this part of the inquiry, is presented in the tables, numbered 2, 3, 4, 5, of the Appendix, prepared and compiled from the official reports of eleven cities, from which the following summary is made:

I.

COST PER HEAD OF POPULATION FOR THE CONSTRUCTION OF WATER-WORKS BY SIX CITIES. (Table 2.)

Pittsburg,	$29.31	Nashville,	$34.60
Cincinnati,	28.36	St. Louis,	37.11
Louisville,	36.14	Kansas City,	28.66

Mean cost per head of population, $32.77.

Note—Excepting Kansas City, these works are all owned by the public, and the water supply is *pumped to reservoirs for distribution by gravity.*

II.

EXPENSE AND REVENUE PER MILLION GALLONS OF WATER SUPPLIED TO SIX CITIES. (Tables 3 & 4.)

	Expense.	Revenue.		Expense.	Revenue.
Pittsburg,	$61.13	$54 30	Nashville,	$24.64	$34 24
Cincinnati,	43.96	75.44	St. Louis,	56.15	68.48
Louisville,	35.79	75.84	Kansas City,	74.74	116.62

Mean ratio of expense to revenue, 35.80.

III.

EXPENSE AND REVENUE PER ANNUM OF WATER SUPPLIED (Table 5 of Appendix,) BY FIVE CITIES OF THE NORTH-EAST AND NORTH-WEST.

	Expense.	Revenue.
Providence, R. I.,	$61,983	$247,543
Brooklyn, N. Y.,	403,747	1,224,563
Detroit, Mich.,	54,451	280,049
Chicago, Ill.,	371,860	1,142,869
Milwaukee, Wis.,	93,000	185,000

Mean ratio of expense to revenue, 32.

ERRATA.—In titles of Tables 4 and 5, Appendix, for "per million gallons," read "per annum."

The mean cost per head of population as shown in Table 2, is $32.77, but as the computation is based on the United States census of 1880, and the reports are taken for later years, allowance is made for increase of population as exhibited in Table 6, which computation reduces the mean cost per capita, to $30.52. Applying this experience to Memphis, and taking its population at 60,000, other things being equal, it would follow that the relative ability of the city to construct a system of water works, is limited to an expenditure of $1,831,200. To compensate, however, for the element of chance that is inherent in every enterprise, $1,200,000 has been assumed as the sum which might be profitably invested, *and all plans that shall cost more than that amount will be treated in this report as impracticable.* And, further, that the question may be relieved of every reasonable contingency, it has been the aim and purpose of this study to restrict the cost of any plan which could fairly meet our case, to $1,000,000.

SOURCES OF WATER SUPPLY.

The question of the source from which a public water supply shall be taken has been so fully discussed through the columns of the press and in social circles, that possibly every scheme for its solution has been proposed. In order, therefore, that each theory might receive an impartial consideration, the subject is now presented and reviewed under the following heads, which are intended to cover the whole ground:

1. Distant sources of supply.
2. Supply from the ground water.
3. Deep-seated sources of supply.
4. The Mississippi River, above the city, as a source of supply.
5. Horn Lake, as a source of supply.
6. Wolf River, as a source of supply.

Before considering these several sources from which it is thought a public supply may be secured, it may be proper to repeat the well-known fact, that water, whether it is found on the surface of the earth, or beneath it, is derived solely from the rain and snow that descends from above. There is no other source of supply. A portion of the rainfall is discharged from the surface in the form of rivers, or is collected in lakes and ponds; a portion is taken up by vegetable substances, another portion is evaporated, and the rest sinks into the earth, passing through strata more or less porous, forming those subterranean reservoirs from which, under favorable conditions, springs issue, or water is obtained by human contrivances, such as common, bored, driven and artesian wells. There are no data, at least sufficient data have not been found in the course of these investigations, from which to estimate the proportion of the rainfall that actually sinks into the ground in the area under consideration, hence a supply from this source must remain conjectural until careful and trustworthy observations have been made to determine it. It is obvious, too, that a more exact knowledge of the geological character of the area, and the climatic influences governing it than are now possessed, are requisite for our guidance.

DISTANT SOURCES OF SUPPLY.

Among the sources that were suggested through the press, from which it is thought feasible to take the supply required by the city, the following may be mentioned:

1. Headwaters of Coldwater River, Miss.
2. Tennessee River.
3. Spring River, Ark.
4. The Springs at Tuscumbia, Ala.

It is believed by many that any one of these suggestions could be formulated into a practicable plan, which should be carried out; but, while entertaining a proper respect for the public spirit manifested by the authors who have published their views, the opinion is ventured that, if the cost of the structures, the financial resources of Memphis, the income to be derived, and the expense required for maintenance, had been considered, these schemes, or any scheme looking to a distant source of supply, would have been dismissed as dreams more idle than a tale out of the Arabian Nights Entertainments.

These speculations are the outgrowth of a strong public desire that lacks all the elements of calm deliberation and patient investigation required for the solution of the subject.

As the question is chiefly confined to the cost of the structures, and as the most cursory examination will satisfy any inquirer of our inability in this respect, it was deemed unnecessary to burden this report with detailed estimates on this branch of the investigation. The aggregate approximate cost of each plan only is submitted, the estimates being made with reference to the most practicable engineering and economical methods, on the assumption that the water to be obtained will be pure, clear and abundant.

1. The cost of the Coldwater plan, including collecting basins, conduits, intercepting culverts, pumping engines, &c., distributing reservoirs, &c., will be - - - - $2,375,000
2. The cost of the Tennessee River plan, embracing vertical engines and stand pipe, &c., two lines of force main, distributing reservoirs, &c., will be - - - - - $6,140,000

3. The cost of the Spring River plan, including pumping engines, &c., force mains, crossing Black, Cache and St. Francis Rivers, the Mississippi River and smaller streams, distributing reservoirs, &c.,&c., will be - - - - - - - - - - - - - $8,240,000
4. The cost of the Tuscumbia plan, including pumping engines, &c., force mains, &c., distributing reservoirs, &c., will be $8,520,000

The cost of supply mains and a distributing-pipe system is not embraced in the foregoing approximate estimates; but as it has already been shown that, we are unable to invest more than $1,200,000 in the construction of water works, a further inquiry into these schemes was thought unnecessary.

GROUND WATER SUPPLY.

That portion of the rainfall which sinks into the earth and is retained in a deposit of gravel or other porous soil near the surface, constitutes the ground water from which source common and driven wells are supplied; and as the depth of a source of supply like this offers an insufficient area for filtration, care should be observed to protect it from surface impurities and drainage pollution. The quantity which may be taken from this source is dependent upon the rainfall and the draught made on it In no case can the supply be maintained unless the rainfall on the surface which contributes to the saturation of the water-bearing deposit is largely in excess of the draught. In dry seasons, the supply will be diminished; if the draught is excessive and continuous, the source will become exhausted. To determine the quantity of water that may be taken regularly and with certainty, the character and extent of the

water-bearing deposit, the drainage area and its inclinations, and the mean rainfall, should be known.

In respect of the popular opinion that driven wells will take more water from a given area than dug wells, owing to certain alleged hydrostatic laws, investigations and experiments (Darcy, Dupont, Luegger, Piefke, of Europe, Marsh, Hoadly, Croes, &c., of America), have so thoroughly proven the fallacy of the opinion as to put the contention beyond the arena of discussion. It is true, however, that for facility and economy of construction, driven wells may be used advantageously for manufacturing purposes, within certain limits. But it is held that Memphis can be supplied from driven wells, the opinion being founded on the successful use of this system at Brooklyn, N.Y., and Jackson, Tenn. It is evident that if the ground water-bearing deposit and the geological conditions of Memphis are similar to those of the cities named, the same results that have been reached by them ought to be accomplished here.

What are the facts in their bearing on the question? The area of Long Island from which the city of Brooklyn derives its water supply may be described as a natural collecting basin and filter gallery. The water shed consists of an irregular ridge of hills, mainly constituted of coarse alluvial earth, boulders and coarse gravel, running sometimes into blue clay. The slopes and spurs on the south lose themselves in a wide gravel plain, which gently declines into the sea. The driven wells are located in this plain, seven and twelve miles distant from Brooklyn, seven miles south of the conduit water shed (which furnishes four-fifths of the supply by means of collecting basins, ponds and reservoirs) and about 7000 feet from high water of the sea, and are supplied from strata said to be protected from permeation of the surface water of the basins of the regular

system. Each system of wells consists of one hundred two-inch tubes, driven from forty to one hundred feet into the ground, in two rows, fifteen feet apart, the tubes in either row being twelve feet apart. The head, or pressure, raises the water in the tubes to a uniform height, sufficiently near the surface that it may be drawn from them simultaneously by suction to a connecting horizontal pipe, and it is pumped and delivered directly to the supply main. Excepting as to its hardness and a slight trace of lime, it is not unlike the surface water collected in the drainage grounds from which Brooklyn takes its principal supply. The daily average consumption of the city in 1884 (official report January 10, 1885) was 38,877,034 gallons, of which 8,500,000 were supplied from the wells.

The driven wells at Jackson, Tenn., lately described in a report to the State Board of Health, in response to inquiries propounded by the writer, are not unlike those of Brooklyn, though differing from them in certain particulars. These wells are twenty-two in number, six inches in diameter and thirty-two feet in depth. The supply now taken from them is 300,000 gallons per day, but a theoretical yield of 3,000,000 gallons in twenty-four hours is conjectured. The water is pumped from the wells and collected in an embankment-basin surrounding them, from which it is again pumped for delivery to the consumer. The deposit from which the water is taken, *fifteen feet below the surface*, is constituted of "coarse sand and white gravel, mixed," on which it is said, an impermeable stratum of blue clay is superimposed. The location of the wells is beyond the present area of contamination of the town.

The geological conditions represented in these two instances do not exist near Memphis, as far as has been discovered in the course of these investigations. It is not

unlikely that ground water, may, at certain seasons, be found in the alluvial deposit lying between the Mississippi River north and west of Wolf River, extending east to Hatchie River nearly to the foothills; but the whole of that territory is periodically overflowed by the Mississippi, is malarial and exposed to decomposing vegetable substances. Certain depressed areas may be found some distance from the city free from these objections, but it is not probable, indeed it is wholly improbable, that a sufficient supply can be obtained from the ground water deposits of this locality, and if obtainable at all, there would be no economy in the plan, which would involve the same expensive structures that were provided for in the old system.

DEEP-SEATED SOURCES OF SUPPLY.

Much of the rainfall that passes into the earth to form the ground water falls upon porous and fissured rock deposits, or on their upturned edges, and is collected in various strata, as illustrated in the well-known basins underlying London and Paris, whose formations have been thoroughly explored. When the water is contained between two impervious strata it may exist under hydrostatic pressure, (Nichols). The strata which afford the most favorable conditions of pressure are those presenting "a broad concentric plane of great circumference around the dip to form a gathering ground," (Fanning) and if percolation is free and the strata inclined, water may be gathered from distant water sheds. The water so collected often becomes changed from its original state of purity by the absorption of gases, and by holding in solution earthy salts and other bodies, which it has met with in its subterraneous passage, (Fanning).

Too much importance cannot be attached to these general conditions, and every practicable means should be employed to acquire a knowledge of the geological area before any costly scheme is undertaken for attempting to obtain a public supply from subterraneous sources. It has been already shown that we do not possess the required knowledge; but, inasmuch as several deep wells have been recently bored within the city limits, which may be called non-flowing artesian wells, an investigation of them was made with a view to gathering information that might bear on the question.

The wells bored in Memphis vary in depth, from 184 to 322 feet; in diameter of bore, from 4½ to 6 inches; water level from the surface, 90 to 115 feet, when the pumps are not in operation, except as to the Natatorium well. The wells of the Tennessee Brewery (one), Bohlen, Huse & Co. (three in use), and the Valley Ice Company (four), examined on the same day, (October 28, 1885,) were found, by calculations made at the time with the assistance of Mr. W. J. McDermott, M. E., to yield respectively, 67,760 (one), 75,068 (three) and 88,790 (four) gallons in twenty-four hours. The depth of these wells is 180 feet. The water is highly charged with iron, shows a trace of sulphur and is unfit for domestic use. The stratum from which it is derived, composed of very fine drift sand some ten feet in depth, the lower portion being too compacted to admit of free percolation, is supplied from a water-shed of limited area, the convergent flow passing through deposits constituted chiefly of ferruginous gravel. The supply yielded has been observed to be greatest during the rainy seasons. The yield, in dry seasons, of the three Bohlen-Huse wells is only ten per cent. greater than that of the one well, 250 feet higher up. The variation of

yield is erroneously attributed to the influence of the Mississippi River; but as the solids held in suspension are being constantly precipitated, and so compact the bed of the river as to retard infiltration, and as the flow of the ground water is towards the depressed bed, it is reasonable to suppose that the variation is alone due to the draught on the stratum and the varying quantity of rainfall

No satisfactory data could be obtained from which to determine the character of the geological formations through which these wells were sunk, except in so far as they indicated them to be the result of the subsidence of waters which at one time overspread this valley. Notes made by Mr. J. B. Cook, Architect, (Appendix No. 7,) at the time of the boring of the Natatorium well (322 feet) confirm this view.

When the well of the Natatorium was opened the water rose in the tube to about 24 feet from the surface of the ground, indicating considerable hydrostatic pressure; but considering the fact that the joints of the tube are not close fitting at first, allowance is to be made for infiltration of the ground water through the interstices, and as pumping was not continuous, the real water level cannot be determined. Moreover, when a deep-seated reservoir is first tapped it is found "lip full," as it were; as its contents are drawn upon, the level will fall in proportion as the draft is greater than the rainfall which supplies it. The effect of a constant draught in permanently lowering the level is afforded in the London wells (varying in depth from 225 to 408 feet), completed in 1842, when the level stood about 93 below the surface of the ground. After pumping was begun, in 1843, the level fell to 115 feet, and stood at 198 feet in 1872. As the level was lowered deeper borings were made, and "adits" (horizontal tunnels) con-

structed to collect the water. The elevation of the water table on completion of the well at Prospect Park, Brooklyn, N.Y., in 1869, was 14.85 feet above tide level. Pumping began in 1870. In 1871 the level was 13.03 feet; in 1872, 10.56; in 1877, 9.21.

The deductions to be drawn from scientific research, supported by experiment and experience, offer no encouragement to the sanguine expectations that have been indulged by many intelligent citizens that the water question would find its solution through a plan of artesian wells. The popular theory that the bosom of the earth, "that mysterious seat of so many fantastical images," holds an inexhaustible supply of pure water, when put to the crucial test of patient and exact investigation, becomes a delusive fancy. The laws which govern exhaustion and replenishment, alterations of level and rainfall, prevail everywhere.

There are numerous artesian wells to be found in various parts of America, as well as in Europe, Asia and North Africa. They were known in China as early as 200 B. C. In one province of Algeria the French have bored large numbers, 158 of which are flowing, but many of them yield water that would be condemned for irrigation in Colorado. In England, where over 2000 have been sunk, it was soon discovered that the yield decreased gradually, and many ceased to flow. The famous well at Grenelle, near Paris, 1806 feet in depth, the Dupont at Louisville (2086), the Belcher (2199), and Asylum (3843) at St. Louis, are all highly charged with mineral salts. These wells are in use for manufacturing purposes in Boston, Chicago and other cities, and there are some 200 in Alabama. There are 40 artesian wells, varying in depth from 40 to 2000 feet, in Manhattan Island, N. Y.

Dr. Cyrus Edson lately read a paper before the County Medical Society of New York, in which he says, "many of these wells are polluted, the best of them containing 30 grains of sewage matter to the gallon of water."

The limited success that has resulted from the borings of the wells of Charleston, S. C., was due to a knowledge of the geological region from which they are supplied. Beginning from Augusta, Ga., and proceeding northeastwardly, a line of exposed granite ridges, elsewhere covered with superficial drift sand and clay, extends northward through North Carolina, Virginia and Maryland. The rainfall sinking into these deposits is carried by gravity to the tertiary basin underlying that city, which is also supplied from the streams of the up-country, the pressure being sufficiently great to discharge the water below the sea level. The principal Charleston well, reported in Croes' Statistical Tables of American Water Works for 1884, is burdened with a bonded debt of $300,000, and supplies for consumption the small amount of 500,000 gallons daily, at a cost of $98.62 per million gallons, *estimated on the bonded debt only*, the works being supported by an annual subsidy of $11,883 paid by the city for fire purposes.

Considering, therefore, our lack of knowledge of the stratifications, the uncertainty of the quantity and quality of the water, the danger of exhausting the supply, the mineral matter with which it is apt to be charged, the cost of structures and pumping for delivery, and that there does not exist one large city which takes its entire public supply from subterraneous sources, it is concluded that Memphis furnishes no exception to the universal experience, and that it would be unwise and hazardous to adopt a plan of artesian wells for a public supply.

THE MISSISSIPPI RIVER, ABOVE THE CITY, AS A SOURCE OF SUPPLY.

The practicability of taking a water supply from a point on the Mississippi river above the city, is a question which involves problems of hydraulics and mechanics that place its consideration beyond the scope of this investigation, and, besides this obvious reason, it is to be remembered, that an able and exhaustive survey of this plan was made by Mr. Chas. Hermany, C. E., aided by Mr. E. S. Chesbrough, as consulting engineer, whose views and recommendations are held by the writer to be conclusive of this branch of the subject. In his report to the Board of Commissioners of the city, made July 15, 1868, the various schemes that were then proposed and carefully considered by him (pages 50–1–2), are summarized as follows: (1) Floating pumping works with flexible shore or land connection leading to a reservoir; (2) laying along the bed of Wolf River, from the Mississippi to the pumping station, a flexible conduit provided with a portal capable of being submerged or floated; (3) constructing a brick or stone masonry conduit which, as it were, might disintegrate piecemeal as the banks are washed away; (4) sinking an inlet tower of wrought iron down to a reliable foundation, with two cast iron inlet pipes extending through the alluvium to the pump wells at the pumping station:—of which plans he says (p. 52) "that in all these schemes there is an effort made to make the structures proposed independent of the changing alluvium in which they must be executed and preserved; and whatever merit any or all of them may possess as mechanical expedients, it is doubtful if any of them come within the province of practical engineering." And he finds that the difficulty in the way

of taking the supply from the Mississippi consists in "the remoteness from the river at which reliable foundations for pumping machinery can be obtained," and "the unstable nature of the material through which a conduit or inlet pipe will have to be built and maintained in position, as well as kept clear from the immense deposits left by the water." In determining upon any plan at this point, provision must be made (p. 53) "for the contingency which may arise from a partial or total destruction of, or rendering inoperative, its inlet conduit." And he recommends as a safeguard to these dangers, an inlet to permit the water being drawn from Wolf River near its mouth.

If the quality of the water now supplied from Wolf River is considered, it is impossible to conjecture what its condition might be a decade hence, should the contingency for its use arise under this plan.

In the several interviews accorded the writer last summer and autumn, Mr. Hermany substantially maintained the positions taken in his report; and it is due to him to say, that the changes of the course of the river which have taken place since, abundantly prove the correctness of the views he held seventeen years ago. If the inlet pipe or conduit had been located opposite Hatchie Lake, it would have been destroyed by the impingement which the river has since made. But it is thought by some that this impingement would result in making Loosa Hatchie the bed of the Mississippi, and that the question would thus be solved. This supposition can only be answered by a query. How long would the Loosa Hatchie remain the bed of the Mississippi?

HORN LAKE AS A SOURCE OF SUPPLY.

The surveys conducted by Mr. Chas. Hermany, C. E., in 1867–8 did not extend to the district in which Horn Lake is situated, which, at that period inaccessible, is now in easy reach of Memphis by railway. But a study of Charts 8 and 9, projected from a trigonometrical survey made in 1867–8 under the direction of Brevet Brig.-Gen. J. B. Comstock, Corps of Engineers, U. S. A., in compliance with an act of Congress, and the personal observations and examinations of the writer, assisted by Mr. J. H. Humphreys, C. E., and Mr. A. J. Murray, C. E., have, in some measure, served the purpose of a preliminary survey. The body of water, known as Horn Lake, at one time the bed of the Mississippi River, lies in the lower portion of an alluvial depression of about twenty-six square miles, embraced in the area extending from the hills south and southeast of Memphis and west of the Mississippi hills, which abut against the east shore or head of the lake, which lies entirely in the lowland. There are, in fact, two lakes, distinguished from each other as North Horn and South Horn Lake, the two basins being separated by a bar, grown up with cottonwood and formed by the silt or deposit precipitated by Horn Lake Creek, whose waters are discharged at a point locally designated as the Bull's Head, communication between the lakes being maintained in dry seasons through sloughs which penetrate the bar. When the Mississippi River overflows the district its waters submerge the separating barrier, and the two lakes, during this period, become one body. The point of separation is situated immediately above the railway station of Lakeview. North Lake, about 25,000 feet in length, mean width, 2600 feet, lies wholly in Tennessee. South Lake, 18,000

feet in length, mean width, 2200 feet, is in the State of Mississippi. The direct distance from Memphis to the north shore of North Lake is ten miles; to the south shore of South Lake, twelve and one-quarter miles. The alluvial area is covered with a growth of hackberry, sycamore, oak, cottonwood, gum, elm and cypress; decayed trees are not numerous and the undergrowth not dense, except where canebrakes occur. The mean level is 210 feet above the datum plane assumed in the U. S. Survey (225 feet below high water at Memphis), or 134.91 feet below the highest point in the city. All, or nearly all, of this district is submerged during extreme high water of the Mississippi, the water marks indicating a height of overflow varying from five to twelve feet.

With the assistance of Mr. A. J. Murray, C. E., soundings and observations of North Horn Lake were conducted, November 22, 1885, at which date the Memphis gauge read 16 02 feet. Water from the Mississippi River was flowing into the lake through the sloughs of the bar separating it from South Horn Lake, which in turn was supplied from Horn Lake Pass, a bayou connecting it with the Mississippi. The soundings taken showed a mean depth of 12 feet; and by comparison with the U. S. chart indicated a slight elevation of the bed of the lake and a gradual drying up of its west end. There are no water courses which empty into it, its source of supply being dependent upon the overflow of the Mississippi and the drainage from the swamps on its north shore. Other observations were made, and the conclusion was reached that North Horn Lake does not present the conditions necessary to a wholesome supply of water.

Assisted by Messrs. Humphreys and Murray, soundings and observations were also made of South Horn Lake.

The mean depth of this body of water is about 22 feet, the soundings showing no variation from the readings of the U. S. Survey of 1867–8, and corresponding very nearly with the soundings of the Mississippi, due west, taken at that time. Its south and east shores are protected from overflow by a substantial levee, beginning at the hills below Lakeview and extending to and connecting with the Mississippi levee near Norfolk on the river, while the north shore, for the most part sandy (apparently a sand bar of the old river), rises gently. When the Memphis gauge reads 13 feet (approximate) and below, the waters of both lakes are discharged into the Mississippi through Horn Lake Pass. When the reading is above 13 feet, the river flows into the lake through the same channel. The drainage of the water-shed, the area of which is estimated at about sixty square miles, is discharged into the head of the lake, a little distance below the confluence of the Cut-Off and Horn Lake Creeks, whose tributaries rise among rolling and abrupt hills, constituted chiefly of clay, sand and ferruginous gravel. The lake is also fed by small creeks and springs on the east shore.

The inflow and outflow of this lake by the Pass, its expanse and depth seem, to that extent, to meet the conditions that are requisite to induce circulation, maintain the water cool through the heat of summer and hinder organic growth, vegetable decay and animal decomposition. The capacity of the basin, estimated at the time the soundings were made, when the banks were not full, is six thousand five hundred million U. S. gallons (6,500,000,000), equal to a supply, at the present rate of consumption of Memphis, of 1083 days, which would be increased 190,000,000 gallons for every five feet of embankment above the water line at the time its capacity was estimated. The mean depth

could be raised to 25 feet and the greatest depth to 40 feet, with comparatively small cost.

The advantages to be gained by utilizing this great basin, capable of storing nearly three years' supply of water, were so apparent that a plan for its protection against overflow, and the reclamation of the objectionable drainage district, was projected, which, however, does not embrace such cognate questions as the purity of the water that might be collected from the Mississippi, or the sufficiency of the water shed tributary to it. These essential factors of the plan are reserved for investigation by competent experts.

"A memorandum of the work required to prevent the water of the Mississippi river from overflowing into Horn Lake," and a map of the district reduced from the U. S. Survey, both prepared by Mr. J. H. Humphreys, C. E., appear in the Appendix numbered respectively 8 and 9. It is proposed to construct a levee, beginning at a point below Mud Lake (see map) connecting with the present levee south of South Horn Lake, extending by a northwest course across Horn Lake Pass (thereby closing it) to the ridge west of the Pass, thence along this ridge northeasterly beyond the west end of North Lake, thence nearly east as far from the river as the ground will permit to a point about three-fourths of a mile below Watson's; thence northeasterly to a point below and near the Fleece place, thence due east across the bottom to the bluff, closing the Cut-Off at the point of crossing. The total length of the levee would be about eight miles, raised four feet above high water, and provided with ample cross sections. The area surrounding the lakes that would be reclaimed by the levee is about fifteen (15) square miles, which it is thought would shortly be relieved of drainage impurities. The overflow

being excluded, a small levee across the junction of the two lakes would entirely isolate South Horn Lake.

A culvert and gate constructed at the crossing of the Pass would provide an outlet and inlet for discharging the water of the lake, or admitting the water of the river. A similar provision would protect the country north of the levee from overflow of the Cut-Off during periods of heavy rain.

Two plans for supplying the basin so reclaimed remain to be considered. (1). To admit the water of the Mississippi River in the winter months, when the volume is great and the temperature low, during which period, by means of an artificial mouth (and gates) opening into North Lake, the waters of the Cut-Off and Horn Lake Creek would be diverted from South Lake. When in the summer and autumn the river becomes too low to flow through the Pass, the aforenamed water courses could be admitted and discharged through the gate of the Pass, thereby inducing circulation. (2). To exclude the water of the Mississippi entirely, and rely on the supply from the Cut-Off and Horn Lake Creek and their tributaries, together with the branches and springs which discharge their waters into the lake.

Before considering the relative advantage of either of these plans the water of the Mississippi at the mouth of the Pass, twenty-six miles below Memphis, (reckoned by the sinuosities of the river) should be analyzed to ascertain whether it is polluted by the sewage and drainage of Memphis. An analysis of the water of the lake in the summer months ought also to be made, to discover the extent of malarial contamination, if any, from the swamps and overflowed lands. Gaugings to determine the volume of flow of Horn Lake Creek and the Cut-Off should be begun at once, and continued until the Memphis gauge reads 13

feet, when the gaugings should be taken at a point on the Pass near the west end of the lake, in order that the supply to be derived from the water shed may be resolved.

It is recommended that these analyses, and an inquiry into the sanitary questions involved, such as the locality, the deposit in the bed of the lake, the efficiency of the means proposed for reclaiming the surrounding area, etc., be refered to Dr. Chas. Smart, U. S. A., and that the gaugings be conducted by Mr. J. H. Humphreys, C. E., who should also be authorized to supervise a preliminary survey of the projected levees.

The general legislation that may be found necessary to carry out this plan should embrace the acquisition of all riparian rights and a control of the littoral of the lake, in order that the public supply may be protected from pollution and contamination.

PLAN FOR DELIVERING THE WATER OF SOUTH HORN LAKE TO MEMPHIS.

The flow of the Mississippi River into the lake, except during periods of floods, is slow and gentle, and a portion of the particles held in suspension is precipitated in its passage. Where the Pass debouches a greater precipitation takes place, causing a gradual filling up of the west end of the lake. As the water flows into the basin it loses its turbidity; and, if left in repose, would reach a satisfactory condition of clearness in from three to five days.

The following plan is submitted for taking the supply from this source :—

Pumping Station.—At a suitable point, near Lakeview, it is proposed to establish the pumping station or buildings to accommodate the pumping machinery, engine, boilers, coal house, etc. The Worthington Pumping Engine is

recommended for the service required by this plan. This engine, being horizontal and direct acting, obviates the use of a stand-pipe, and when put in operation requires no care beyond that necessary to keep its parts in proper working condition. It is economical in the consumption of fuel, etc., is employed in the water works of some two hundred cities, among which may be mentioned New York, Brooklyn, Philadelphia, Buffalo, Boston, St. Louis and St. Joseph; and it was lately adopted by the British government for service in constructing the projected railway from Suakim to Berber, in Egypt. It also possesses the economic advantage of requiring light foundations and small superstructures. The service that would be required of it for this plan, is almost parallel with what it is performing for the Hackensack Water Works, N. J., examined by the writer last autumn. The station of these works is located at New Medford, from which place the water is pumped 14 miles against a static head of 173 feet, through a 24-inch cast iron pipe and delivered to the reservoir at Hackensack; or, by means of a stop-gate or by-pass, the water is diverted from the reservoir and delivered direct for consumption, in the same manner employed by what is popularly known as the Holly System.

Force Main.—The water is to be brought from the lake through a suction pipe to the pump well in the pumping station, and by the power of the engines delivered through one line of cast iron pipe, thirty (30) inches in diameter, to the distributing reservoir, to be described hereafter. The most direct and feasible line from the pumping station to the distributing reservoir, estimated at eleven and one-quarter miles, is to be adopted; and the pipe is to follow the contours of the surface, thus avoiding deep cuts and

tunneling, at a depth sufficient to protect the pipe from injury and the water from freezing. (See Map 10 of Appendix.)

DISTRIBUTING RESERVOIR.—It is not to be supposed that any one who has studied his report, will doubt that the site chosen by Mr. Hermany is the only one within our reach, sufficiently elevated, from which water can be distributed to the city, by gravity. "The site selected," (he says) "for the distributing reservoir, is on the highest ground embraced within the limits of the surveys made, and will enable the maintenance of a greater head upon the distributing pipes than any other natural elevation within the reach of the city, or available for the purpose. It is located on the west side of the Hernando road, between McLemore and Richmond avenues, S. 27½°, E. 13,050 feet, or $2\frac{47}{100}$ miles from the centre of Court Square," (known as the old race course). Here it is proposed to construct a distributing reservoir having a storage capacity, when filled twenty feet deep, of 21,666,250 gallons, or three and a half days' supply, (another similar basin to be constructed later on), the flow line of which will be $68\frac{2}{10}$ feet above Court Square, and with which connection may be made (if thought expedient) with the existing system of distributing pipes, for delivering the water by gravity.

But it has been doubted whether this location is sufficiently elevated for distribution by gravity. As a means of determining the question, a comparison was instituted between the pressure produced by direct pumping from the station on Wolf river and the gravity pressure from the proposed reservoir, Hermany's tables of levels being followed, on the assumption that no allowance had been made for loss of head by draught and friction. With this view, under

the orders of Capt. Jas. E. Clary, C. F. D., and in presence of two or more witnesses, the pressure at 28 city fire hydrants was taken between the hours of 2 and 4.25 P. M., October 20, 1885, and 9.50 and 10.40 A.M. of the day following, as shown in his report (No. 11 of Appendix). By comparing the Clary-report with the Hermany-levels, it will be seen that the pressure to be afforded by gravity will be greater than that given at the time mentioned, by direct pumping. However, as the elevation of the site is none too great, the head may be better maintained by a system of independent supply-mains; and, when the population grows sufficiently dense, stand-pipes could be made self-sustaining, as auxiliaries to the reservoir, for high-service purposes.

Before concluding this branch of the subject, mention should be made of a simple, automatic Air Compressor (Clayton's patent) successfully employed, for aeration, by the Hackensack Works, at a cost of $1500 for the plant and $500 per annum for maintenance, which might be made useful in the Horn Lake plan.

WOLF RIVER AS A SOURCE OF SUPPLY.

Wolf River is characterized by three distinct fluvial forms. (1). Below Raleigh, excepting during heavy floods, it is a sluggish, torpid bayou, whose waters are stained and muddy the greater part of the year. (2). Above that village the stream presents an active current, fed by creeks and springs; but during periods of storms its waters become turbid from the fine particles of yellowish-red clay that are washed into it from the hills (3). In the intermission of rains the river above Raleigh may be compared to a canal, through which the aggregated waters of numerous springs and brooks are discharged. But certain prejudices exist

in the public mind against the river as a source of supply, founded in the belief that the water now in use is the same as that recommended in Hermany's report. There has never existed an opinion more erroneous on a question so vital as this. The river *below* Raleigh was expressly condemned as a source unfit for domestic use, independently of its turbidity—the main cause of popular discontent. It was pointed out that the drainage of Cypress and Cane Creeks, extending to the suburbs of the city, affected the water "prejudicially and seriously;" that at Raleigh "the surface of the water at ordinary summer stages is one foot and a half above high water of the Mississippi and fifty feet below Court Square," and that it was "desirable to go beyond the back water from the Mississippi in order to obtain the water from the live stream." Again, in the first report submitted to the *original* Memphis Water Company by Mr. G. W. Pearson, Constructing Engineer, it was ingeniously made to appear, by inference, that the analysis conducted by Prof. Joseph M. Locke and Mr. Jno. Locke, M.D., was an analysis of the water taken at or near the present pumping station, when, in point of fact, the water examined and recommended by these chemists was collected by Mr. A. W. Gloster, C. E., of Hermany's staff, from the river near Massey's farm, 7 3-10 miles above Raleigh.

The objections to the present point of intake, pointed out seventeen years ago by Mr. Hermany, have been gravely aggravated since by reason of increased population, the establishment of adjacent factories, the use of the river as a storage basin for green logs, and the discharge of the sewage of the city so near to the mouth of Wolf River that in periods of high water the diluted sewage is forced back into the stream above the point of intake of the water supply. This back flow of the Mississippi, bearing the

sewage of the city, was established by experiments conducted through several months by Major W. H. H. Benyaurd, U. S. Engineer Corps, reported to the Legislative Council Nov. 4, 1881. Dr. G. B. Thornton, President of the Board of Health, in that part of his third annual report reviewing this officer's report, reached the conclusion that there existed sufficient grounds "to at least establish a well-founded suspicion as to the purity of the present water supply," * * * and that "there need be no further argument to condemn the present arrangement." It is his opinion to-day that all of the lower portion of the river should be given up to pollution, that the establishment of factories on its banks might be permitted and encouraged. Moreover, it may be safely affirmed that, no water supply to which public opinion is opposed, whether or not it be satisfactory from a purely scientific point of view, should be maintained. Public prejudice acts on the imagination to the extent of influencing health; every ailment or disorder is attributed to the supposed objectionable supply, and in times of epidemic diseases it has been observed that the state of mind has largely influenced the state of health. (Nichols).

In considering Wolf River as a source of supply it is assumed and believed, after careful investigation, that the water above Raleigh is pure and wholesome, and when not turbid is suitable for domestic use. In respect of the quantity required, gaugings were made by Mr. Hermany, Oct. 9, 10, 12, 1867, in which season little or no rain had fallen, and "the average discharge during the time of these observations was found to be 8,636,775 U. S. gallons per hour, being equal to nearly eight times the minimum discharge of the Croton River supplying the city of New York."

With the view of determining the time required for the subsidence of the water when turbid, a series of observations were made during the months of November and December, 1885. Three days after a heavy rain, Nov. 10, the fire cistern corner Beale and Second streets and the fountain basin in Court Square were emptied, refilled from the hydrants and the supply cut off, under the personal supervision of Capt. Jas. E. Clary, C. F. D. Bottles (half-gallon) were filled at various depths from these reservoirs, securely sealed in the presence of witnesses and stored in the office of the Chief of the Fire Department on Nov. 10, 12, 14, 16, 18 and 20. The water at this time was very turbid, yellow and highly charged with fine particles of clay held in suspension. Observations were made from day to day for fourteen days. On the sixth day a slight precipitation was noticeable, the water clearing above—about one-sixth of the whole mass; on the fourteenth day one-half of the quantity was relieved of the clay, the lower half remaining in its original state, the cleared part retaining a deep yellow color more or less translucent. On Jan. 22, 1886, the subsidence was complete, the water showing a brownish-yellow opaque color.

While making a reconnoissance (Nov. 13, 1885) near where the Louisville and Nashville Railway crosses Wolf River, it was noticed that the stream presented a milky-gray appearance and was very turbid. The current was active and rain had fallen two or three days before. For the nine preceding days there had been 2.93 inches rainfall at Memphis and 3.50 inches (estimated) at this point and above. Five days later, a barrel of the water was taken from the river at the railway crossing (from which one-half gallon was bottled and sealed) and brought in by Capt. Clary, (Nov. 18), when it was observed that the water was fairly

clear, azure in color, and desirable for domestic use. On the third day it had entirely cleared, showing a slight precipitation of fine gravel and sand and a trace of clay. Simultaneously with the taking of this sample, water was drawn from the hydrant, corner Second street and Second alley, (which was first allowed to run off) and found slightly turbid and stained. The turbidity disappeared on the fifth day; the yellow stain remained unchanged. On Dec. 9 Capt. Clary again filled and sealed bottles of the water taken at the railway crossing and the pumping station at Memphis. These samples were thoroughly shaken up on the 11th (when observations began) and were turbid from recent rains. The sample from the railway crossing was found free of stain on the sixth day, but murky; on the eighth and ninth days, clearer; on the tenth day, suitable for domestic use; decanted on the fourteenth day, it presented a clear, azure-gray color, wholly free from suspended particles. Observations of the pumping-station-sample were conducted *pari passu*. On the sixth day, the water was very murky and yellow; on the eighth and ninth days about forty per cent. appeared fairly clear and stained, the remainder turbid; on the tenth day increased precipitation was noticed; on the fourteenth day it was decanted, exposing a deep yellow, transparent color, undesirable for domestic purposes.

The conclusions to be drawn from these experiments are (1) that, during periods of intermission of rainfall, the turbid water of Wolf river, above Raleigh, is discharged from its bed, in from three to five days, a fact confirmed by the observations of old citizens living near the stream; (2) that when the turbid water has passed below Raleigh, the supply is maintained from springs at the head-waters and along its course; (3) that the turbid water will attain,

by subsidence, a satisfactory condition of clearness in ten days, or less. The months, however, in which the rainfall is greatest and sometimes continuous for several days, are to be taken into the account, in projecting any plan for supplying clear water all the year round. This point considered, it is believed (see mean rainfall) that during the months of May, June (now and then varying), July, August, September, October and November, pellucid water can be supplied from Wolf river, at or near the crossing of the Louisville and Nashville Railway; in December and January the water will be clear; in February, March and April, varying from clear to fairly clear, and at all times free of stain, wholesome and potable.

WOLF RIVER PLAN.

The plan proposed in the Hermany survey for conveying the water of Wolf river, by gravity, from a point on the Massey farm, (11.87 miles, almost due east from Court Square) by means of a brick conduit to settling reservoirs located between the Louisville and Nashville Railway and the old Raleigh road in Memphis, was examined in the course of these investigations and found too expensive for our present population. A plan to construct settling reservoirs near Massey's was studied and abandoned, on account of engineering objections and the cost involved for building two miles of railway to connect the pumping station with the Memphis and Charleston Railway.

It has already been shown that our means and population would not justify the projecting any plan more distant.

Four and a half miles below Massey's, the Louisville and Nashville Railway crosses Wolf river, affording the means of transportation and where the water is as desirable as

at Massey's; but where the topography and river-level do not admit the locating of settling basins that could be satisfactorily or economically constructed, and supplied by gravity, from the river. At this juncture the inquiry presented itself, why not simplify the question and locate the settling and distributing reservoirs on the same site? Why not make the two systems one? Could not a settling basin be made to subserve the purpose of a distributing reservoir? It is believed that these questions may be affirmatively and satisfactorily solved. A plan for taking the water from Wolf river, near the crossing of the Louisville and Nashville Railway and delivering it direct to the elevated ground already described, there to be collected in settling basins of ample capacity to allow the water to become clear by subsidence, and be delivered by gravity to the city, is deemed practicable.

Dam.—It is proposed to build a dam across the river, near this point, of a height to raise the level of the river in dry seasons to avoid the necessity of lifting the water by pumping machinery.

Conduit.—From the river, above the dam, a brick conduit is to be constructed, furnished with the required stop gates, etc., leading to the pump well in the pumping station, shown in map No. 12 of the Appendix, by means of which the water is to be delivered into it, by gravity.

Pumping Station.—The pumping station is to be located near the river, above overflow, within reach of the railway by a side track, and the water pumped through a 30-inch cast iron pipe, laid in a direct line, cross country, and following the contours to the site of the settling and distributing reservoirs (old race course), traversing a distance of nine miles. (See map 12 of Appendix). As

in the Horn Lake plan, the Worthington steam pumping engine is to be employed for delivering the water to the basins; and, in other respects, the pumping station is to be the same as the one projected for that plan.

SETTLING AND DISTRIBUTING RESERVOIRS.—In order that the water, when turbid, may be allowed ample time to subside to a condition of clearness desirable for domestic consumption, it is proposed to construct on the aforementioned site three basins, each of a capacity of 52,000,000 gallons, (height of embankment and flow line the same as described in the Horn Lake distributing reservoir), which are to serve the purpose both of settling and distributing reservoirs. Basins of these volumes will admit of *eleven days repose of the water* and furnish a supply, reckoning the daily consumption at 6,000,000 gallons, of about twenty-five days, as all the water could not be drawn off. Whenever the consumption reaches 10,000,000 gallons per twenty-four hours, another basin should be added, which would then allow ten days for clearing the water, when turbid. The three basins being filled and cleared, one is to be drawn off and refilled. The other two basins would be emptied in turn, and meanwhile the water in the first basin cleared, allowance being made for the time necessary (four and a half days) to pump the water from the station.

A system of basins large enough to secure an ample supply of clear water is necessarily expensive, but the advantages to be gained from an increased revenue counterbalance the apparent burden arising from first cost, and, in fact, cheapen the cost of maintenance. These counterbalancing advantages are to be found in the greater consumption of clear water; economy in flushing the mains; preservation of closet valves; discontinuance of the prevailing

habit of allowing the water to run that accumulated mud may be washed out and the clogging of service pipes prevented; a more general use of water meters, the disuse of mud drums in factories, the elimination of matter held in suspension, and the improvement of the public health as a consequence.

FILTRATION.

The filtration of water on a scale adapted to public service, though generally practiced in Great Britain and on the continent of Europe, has not been employed in the United States, the cities of Hudson and Poughkeepsie, N.Y., furnishing the only notable exceptions. The processes used in some small western towns are not regarded as worthy of mention in this connection. The great cost of a filter plant, such as would be required for the wants of Memphis, if added to the expenditure necessary to establish a permanent system of water works, would put the whole scheme so far beyond our means that it is thought inexpedient to enter into the details of this branch of the subject. In pursuance, however, of the request of the Committee, an ingenious mechanical device, largely used by hotels and factories, known as the Hyatt Filter, manufactured by the Newark Filtering Company, was examined at Newark, N. J., with a view of its adaptability to our requirements, with the assistance of Mr. John W. Rutherford, C. E., of New York, to whom the writer is indebted for this service and for many others, voluntarily given, as well as for valuable suggestions, documents, estimates, etc. The Hyatt Filter is a cast-iron tank divided into two chambers, the lower chamber containing the filter bed, the upper one being employed for washing the bed when foul. The unfiltered water, charged with certain coagulants, enters the

tank by a valve, and descending through the filter bed escapes through a perforated diaphragm at the bottom, and passes out by an outlet in a filtered state. When the filter bed requires washing the outlet is closed; the water is let into the lower chamber, and by hydrostatic pressure is forced to the upper chamber, carrying with it the filtering materials by means of numerous tubes. The water in the upper chamber is agitated and re-supplied until the filter bed is cleansed of its impurities, the water being meanwhile discharged by a waste pipe. The filter bed, restored by this process, to its original condition, is returned to the lower chamber for use. The service is automatic, requiring the duty of one operator for opening and shutting the valves. The coagulants consist of what the Newark Filtering Company designate as "metallic iron," through which material the water passes, and is then charged automatically with from one-half to one grain of lime per gallon before it enters the filter chamber, coagulation and filtration being simultaneous. These coagulants are harmless and to some waters improving. For domestic use alum is used as a coagulant.

It is claimed that while filtration on the large scale by the recognized methods proceeds at an average rate of four gallons per square foot of filter surface per hour, through an average depth of one foot of sand and the usual underlying materials, requiring the bed to be washed by manual labor every fourth week, the Hyatt apparatus will filter 150 gallons of water per square foot per hour, through a depth of six feet of sand, the bed to be washed every twenty-four hours by mechanical and automatic means. Each cubic foot of sand is to perform eight times the work of the old method and to be washed twenty times as often. A conditional proposal for filtering the Memphis water supply

was submitted by the Newark Filtering Company, and is filed with this report. This proposal is for a plant of three filters, (each to filter 2,500,000 gallons per twenty-four hours) thirty feet in diameter, capable of resisting a pressure of forty pounds to the square inch, with a frictional resistance not to exceed ten pounds per square inch, requiring five per cent. of the quantity of water filtered for washing the bed, which is to be done in less than one hour with a head of from twenty to forty feet, at a cost for coagulants not to exceed one dollar per million gallons and the service of two ordinary laborers. There seems to be no ground for doubting the success of this filter in its adaptation to the purposes of textile and paper factories, but no opinion can be ventured as to its practicability for public use in Memphis. This is a question pertaining to the hydraulic and mechanical engineer, and it is recommended that it be referred to approved experts for determination.

WAYS AND MEANS.

Two plans for obtaining means to construct the works present themselves: (1) To issue bonds secured on the plant, for a sum sufficient to cover the whole cost; (2) to issue stock and bonds in the proportion of one of stock to four of bonds, a dividend of not less than six per cent. to be guaranteed on the stock; or, the stock may be owned by the city. The latter plan would facilitate the sale of the bonds and enhance their value. There are no securities held in such high esteem by investors, or that can be more readily negotiated, than water bonds, provided the security on which the loan is founded is satisfactory. The works should be owned by the city, controlled by competent officials placed beyond political influences,

and the plant and all improvements that may be made to it, mortgaged to secure the bonds. It should be clearly shown that the revenue to be derived from the works will be sufficient to pay the cost of maintenance, the fixed interest charges and the betterment and enlargement of the plant. If it shall be further shown that the population of the city is increasing and is likely to continue to increase, the security of the bondholder will represent a property of increasing value, producing, year by year, larger revenues. Many instances might be cited to illustrate the steady growth in value of water works plants, as far as it concerns the bondholder; the experience of Louisville, however, will alone be mentioned. The cost of the water works of that city, to January 1, 1866, was $1,090,243.16, the bonded debt $900,000. Up to Jan'y 1, 1885, $3,795,173.99 had been invested in the plant, the bonded debt reduced to $840,000; and a surplus now remains, which with the accruing revenues, is found sufficient to enable the engineer in charge (Mr. Hermany) to undertake the construction of an entirely new and costly pumping plant.

The information gathered in New York, as to the feasibility of negotiating the required loan, warrants the assertion, that if the aforementioned conditions are complied with, a six per cent. bond can be placed at par; and, since the details of legislation and organization are within our power to control, the questions of revenue and expense alone remain to be considered.

In the approximate estimates of costs, which are submitted in the Appendix, no account is taken of those parts of the existing works which are common to any system that may be adopted; but it was found necessary (while disclaiming any intention of prejudicing the rights or the value of the property of the Memphis Water Company), to project *de*

novo, a supply-main and distributing pipe-system, embracing 34 miles of 30, 16, 12, 10, 6 and 4 inch pipes, which is estimated to cost, approximately, $260,000. This sum is added to the cost of each plan in the summary, but is not embraced in the estimates made in detail.

The gross revenue of the Memphis Water Company for the year ending July, 1882, was $60,000; in 1884, $80,000 (see Croes' Statistical Tables), an increase of 33⅓ per cent. in two years, or $10,000 per annum. The returns for 1885 are not yet published, but it is understood that the same ratio of increase was maintained, or nearly so. Without making any allowance for increased consumption of a better quality of water than is now supplied, if this ratio of increase is preserved until 1889, earlier than which period new works could not be completed, the company's gross revenue would then be $130,000 per annum.

It is assumed, however, that the gross earnings in 1889, from a satisfactory water supply, will be $120,000. The cost of maintenance of the Memphis company in 1882, was 40.33; in 1884, 43.75 of the gross revenue, but it will be admitted that this cost would be less, if the works were owned by the city. As shown in tables 4 and 5 of the Appendix, the mean cost to the cities cited was, respectively, 32 and 35.80. If the superior character of the steam pumps to be employed, the better quality of the water to be served and the greater economy of public management are considered, it would be safe to estimate the cost of maintenance at 35.

The following estimates are based on the foregoing facts:

The cost of the South Horn Lake plan will be - - - - - - - - -		$958,599
The revenue from water rates will be		120,000
The cost of maintenance will be - -	$42,000	
The interest on the cost of the plant per annum will be - - - - - -	57,516	99,516
The revenue, in excess of the cost of maintenance and interest, will be -		$20,484
The cost of the Wolf River plan will be - - - - - - - - - - - - -		$1,074,528
The revenue from water rates will be		120,000
The cost of maintenance will be - -	$42,000	
The interest on the cost of plant will be - - - - - - - - - - - - -	64,472	106,472
The revenue, in excess of the cost of maintenance and interest, will be -		$13,528

As these estimates relate to the ratio that expense bears to revenue, which determines the gain or loss on the investment, it is not thought necessary to submit the estimates that have been made of the cost of the water per million gallons. "The annual cost of operation of the works is the true criterion by which the relative value of the project is to be judged. It includes the interest on the capital invested, the supervision and maintenance of structures and the cost of pumping." (Croes.)

If the Hyatt Filter, after examination by experts as recommended, should be found a practicable and permanent means of filtration, adapted to clearing the water of Wolf River, without interference with the proposed gravity system of supply, the estimates of the cost of the Wolf River

plan would be reduced about $150,000, by reason of the smaller reservoirs that would be required. The revenue per annum in excess of the cost of maintenance and interest would be approximately, $15,528, after taking into account the increased expense of filtering the water.

SUMMARY OF COST OF EACH PLAN.

APPROXIMATE ESTIMATE OF COST OF SOUTH HORN LAKE PLAN.

Levees, conduits and gates, land and right of way	$114,000
Engine house, pump well, boiler and coal houses	40,588
Force-main, (including inlet to pumping station) to distributing reservoir	292,422
Distributing reservoir of capacity for three days' consumption, including real estate	103,989
Effluent chamber, pipes and stop-gates	19,318
	$570,317
Contingencies and omissions 10 per cent. on $562,817	56,282
	$626,599
Two Worthington steam pumping engines, including steel boilers, foundations and connections, put in place, capable of pumping 10,000,000 gallons per day	72,000
	$698,599
Supply mains and distributing pipes	260,000
Cost of South Horn Lake plan	$958,599

See Exhibit of Details, Nos. 13, 14, 15, 16, of Appendix.

APPROXIMATE ESTIMATE OF COST OF WOLF RIVER PLAN.

Dam, conduit and gates, land and right of way	$49,300
Engine house, pump well, boiler and coal houses	40,588
Force-main from pumping station to reservoirs	235,945
Settling and distributing reservoirs of capacity for twenty-four days' consumption - - -	362,480
Effluent chamber, pipes and stop-gates - - -	24,147
Contingencies and omissions on $300,680 at 10 per cent. - - - - - - - - - - - - - -	30,068
	$742,528
Supply mains and distributing pipes - - - -	260,000
Two Worthington steam pumping engines, including steel boilers, foundations and connections put in place, capable of pumping 10,000,000 gallons per twenty-four hours -	72,000
Cost of Wolf River plan - - - - - -	$1,074,528

See Exhibit of Details, Nos. 17, 18, 19, 20, of Appendix.

The conclusions that have been reached from the investigations made to this date, are summarized as follows :

1. That all the schemes which have been proposed for taking the supply from distant sources, or from any source distant more than twelve miles from Memphis, would involve a cost beyond our present means.

2. That the geological conditions necessary for obtaining an adequate supply of wholesome water, by means of bored wells, known as the gang well or Andrews' system, do not exist in or near Memphis.

3. That no certain reliance can be placed on the results obtainable from deep-seated or artesian wells for public

service, because the sources of supply are unknown, the water is likely to be charged with mineral substances, the supply is liable to become exhausted, and, that the cost per million gallons would be greater than the cost of a surface supply.

4. That the several schemes proposed for taking the supply from the Mississippi above the mouth of Wolf River, are exposed to engineering objections; and, that if any one of these plans might be so projected and executed as to be made permanent, the cost would exceed the ability of the present population of Memphis.

5. That the plan proposed for taking the supply from Wolf River, near the crossing of the Louisville and Nashville Railway, is practicable; that the revenue to be derived will maintain the works and pay the interest on the plant, and the water supplied will be of a desirable quality for domestic use

6. That considering the manifest advantages to be gained by utilizing South Horn Lake as a collecting basin, presenting a storage capacity for nearly three years' supply, the analysis of the water, the gaugings of the water-shed and the sanitary questions involved, should be determined by experts as recommended, before any plan is adopted.

7. That the Hyatt method of rapid filtration should be investigated by competent hydraulic and mechanical engineers, in order that that branch of the question may be determined.

It may seem that more space has been devoted in this report to the examination of various projects, than their importance demanded; but, considering the prominence that had been given to them by the press, it was deemed best to present the whole case for the benefit of those persons who had not fully investigated the subject.

It is gratifying to the writer to have occasion to express his appreciation of the cheerful and disinterested assistance and advice given him by many gentlemen during the course of these investigations; and to Mr. Jno. W. Rutherford, C. E., Mr. Frank Rudd, Counsellor at law and Mr. W. A. Perry, of New York; Mr. Peter Milne, Jr, purveyor to the Brooklyn Water Works; Mr. C. D. Brush, C. E., and Mr. Chase, M. E., of New Jersey; Mr. Charles Hermany, C. E., of Louisville; Judge Jno. M. Lea and Dr. J. Berrien Lindsley, of Nashville; Mr. W. J. McDermott, M. E.; Mr. J. H. Humphreys, C. E.; Mr. N. Merriwether, C. E.; Mr. A. J. Murray, C. E.; Capt. J. C. Clary, C. F. D.; Mr. Sam. Tate, Jr.; Mr. D. T. Flannery, Signal Service; Mr. F. W. Royster, Mr. G. H. Sease, Mr. J. B. Cook and Mr. E. C. Jones, architects; Mr. Jno. Gunn, Mr. Jas. Lee, Jr., Mr. J. M. Kloster, C. E., Mr. J. M. Keating, and Mr. H. M. Doak, of Memphis, and others whose names are not now recalled, he begs to extend his grateful acknowledgments for their services.

COLTON GREENE.

APPENDIX.

TABLE 1.

AREA IN SQUARE FEET OF *SEWERED* DISTRICT, INCLUDING PART OF FIRST, SECOND, WHOLE OF THIRD AND FOURTH, PART OF FIFTH, WHOLE OF SIXTH AND SEVENTH, PART OF EIGHTH AND TENTH WARDS—51,484,950 SQUARE FEET.

AREA IN SQUARE FEET *NOT SEWERED.*

First Ward	395,000
Second Ward	142,500
Fifth "	190,000
Seventh "	1,081,875
Eighth "	5,481,625
Ninth "	11,351,625
Tenth "	19,139,450
	37,782,075

AREA *NOT SEWERED* IN SUBURBS.

	Square Feet
North of Taxing District limits, bounded by Brinkley Street, Breedlove Avenue and Winter Street	19,219,500
East of Taxing District limits, between Winter Street and Union Avenue	13,541,000
East, between Union Avenue and Broadway, and on a line running south from Breedlove Avenue	11,388,000
South of Taxing District limits, between Broadway, Iowa Avenue, Elmwood Cemetery, Walker and Gaines streets	31,885,000
	76,033,500

ESTIMATED POPULATION.

Taking as a basis the *sewered district*, 51,484,950 square feet, at 8½ persons per 10,000 square feet, the population would be		43,752
Taking at same rate the unsewered part of First Ward	395,000 sq. ft.	
Second Ward	142,500 "	
Fifth "	190,000 "	
Seventh "	1,081,875 "	
Eighth "	5,481,625 "	
	7,291,000	
	Population,	6,297
Taking four persons per 10,000 square feet, Ninth Ward	11,351,625 sq. ft.	4,540
Taking two persons per 10,000 square feet, Tenth Ward	19,139,450 "	3,827
Taking one person per 10,000 square feet, suburbs	76,033,500 "	7,603
		66,019

November 30th, 1885. ANTHONY ROSS, C. E.

TABLE 2,

Showing the Cost per Head of Population of the Water Works of six Cities, compiled from Official Reports, on a basis of the U. S. Census of 1880.

City	Date of Report	Owned by	Source of Supply	Mode of Supply	Cost of Works	Bonded Debt	Interest	Cost per Head of Popular'n	Mean cost per Head
PITTSBURG.....	July, 1884	City	Alleghany River	P. R.	— —	$ 4,582,500	7	29.31	
CINCINNATI.....	Dec , 1883	City	Ohio River	P. R.	$ 7,236,395	1,449,957	7-6	28.36	
LOUISVILLE.....	Dec., 1882	City	Ohio River	P. R. & S. P.	4,482,145	900,000	6	36.14	$ 32.77
NASHVILLE.....	July, 1884	City	Cumberland River	P. R.	1,500,000	75,000	6	34.60	
ST. LOUIS.....	July, 1884	City	Mississippi River	P. R.	13,000,000	5,250,000	6	37.11	
KANSAS CITY...	Sept., 1884	Company	Kansas River	Pump Direct	1,150,000	1,500,000	6	28.66	

NOTE.—*Cost of Work* embraces cost of additions made to original plant.

Nashville.—$200,000 bonds since issued for improvements.

P. R.—Read, Pump to Reservoir. S. P.—Pump to Stand Pipe.

TABLE 3.

Expense and Revenue per Million Gallons of Water Supplied to Six Cities, compiled from Official Reports.

City	Year of Return	Gallons Supplied per day	Expense per Million Gallons	Interest on Bond per Million Gallons	Total Cost per Million Gallons	Revenue per Million Gallons	Net Profit per Million Gallons	Net Loss per Million Gallons
Pittsburg.....	July, 1884	20,180,000	$ 17.52	$ 43.51	$ 61.13	$ 54.30	— —	$ 6.83
Cincinnati.....	Dec., 1883	19,401,200	29.27	14.69	43.96	75.44	$31.48	—
Louisville.....	Dec., 1882	8,202,206	17.76	18.03	35.79	75.84	40.05	—
Nashville.....	July, 1884	6,000,000	21.90	2.74	24.64	34.24	9.60	—
St. Louis.....	July, 1884	30,000,000	27.39	28.76	56.15	68.48	12.33	—
Kansas City.....	Sept., 1884	4,500,000	19.93	54.81	74.74	116.62	41.38	—

TABLE 4.

Expense and Revenue per Million Gallons of Water Supplied to Six Cities, compiled from Official Reports.

City	Date of Report	Expense	Revenue	Mean Ratio of Expense to Income
Pittsburg	July, 1884	$ 140,000	$ 400,000	
Cincinnati	Dec., 1883	207,311	534,281	
Louisville	Dec., 1882	53,180	227,052	35.80
Nashville	July, 1884	48,000	75,000	
St. Louis	July, 1884	300,000	750,000	
Kansas City	Sept., 1884	32,750	191,561	

TABLE 5.

Expense and Revenue per Million Gallons of Water Supplied by Cities of the Northeast and Northwest, compiled from Official Reports.

City	Date of Report	Method of Supply	Population U. S. Census	Cost	Bonded Debt	Expense	Income
PROVIDENCE, R. I.	Dec., 1883	P. D. & P. R.	104,857	$ 4,928,682	— —	$ 61,983	$ 247,543
BROOKLYN, N. Y.	Dec., 1883	P. R.	566,663	11,990,592	$ 10,452,000	403,747	1,224,563
DETROIT, MICH.	Dec., 1883	P. R.	116,340	3,316,000	1,555,000	54,451	280,049
CHICAGO, ILL.	Dec., 1883	P. to S. P.	503,185	9,695,956	4,955,000	371,860	1,142,869
MILWAUKEE, WIS.	July, 1884	P. R.	115,587	2,400,000	1,485,000	93,000	185,000

Mean ratio of expense to revenue, 32.

NOTE.—P. D. & P. R.—Read, Pump Direct and Pump to Reservoir.

P. R.—Pump to Reservoir.

P. S.—Pump to Stand Pipe.

TABLE 6,

Showing the Mean Cost per Head of Population of the Water Works of six Cities, based on Actual Population at the date of the Latest Published Official Reports.

City	Population in 1870 U. S. Census	Population in 1880 U. S. Census	Year of Last Report	Ratio of Increase per Year	Population at date of Last Report	Cost of Water Works
PITTSBURG	86,076	156,389	July, 1884	8.17	184,519	$ 4,582,500
CINCINNATI	216,239	255,139	Dec., 1883	1.80	266,816	7,236,395
LOUISVILLE	100,753	123,758	Dec., 1882	2.28	128,352	4,482,145
NASHVILLE	25,865	43,350	July, 1884	6.76	50,394	1,500,000
ST. LOUIS	310,864	350,518	July, 1884	1.27	366,311	13,000,000
KANSAS CITY	32,260	55,785	Sept., 1884	7.29	65,195	1,500,000
				Totals	1,061,587	$ 32,301,040

Mean cost per head of population, 30.52.

NO. 7.

COOK'S NOTES ON THE BORINGS OF THE NATATORIUM WELL.

The well was started June the 9th, 1885, and finished August 24th, 1885. Clear water was reached at a depth of 322 feet. During the boring and from specimens of the formation passed through, no distinct evidence of geological stratification showed itself; it rather gave evidence that the boring was passing down to a vast basin, which has for centuries been receiving alluvium deposits by inundations and the backing of waters, and with the waters the silt of the Mississippi River and the water sheds of the Mississippi Valley. When by boring the basin was reached, a plane of clear water was reached and ascended to within about twenty feet of the surface of the ground, and from thence was lifted and pumped into the swimming tank of the Natatorium. A transcript of my notes taken at the time of boring, giving the various deposits passed through to the basin and plan of water, is as follows:

Given in tenths—

1st.	10 ft.	Made ground.
	10 ft.	Swamp ground and water (surface).
	30 ft.	Loam and water.
	10 ft.	Submerged forest (bog timber).
	40 ft.	Silt.
	20 ft.	Stiff brown clay.
	20 ft.	Silt.
	20 ft.	Pipe clay.
	20 ft.	Quicksand (light sand and water).
	20 ft.	Brown clay and water.
	100 ft.	Greyish brown clay (grey sand in the clay).
	20 ft.	White sand and pure water at this point, and for two feet downward water was taken for the Natatorium.
	2 ft.	

JAMES B. COOK, *Architect.*

November 4th, 1885.

NO. 8.

HUMPHREYS' MEMORANDUM OF THE WORK REQUIRED TO PREVENT THE WATER OF THE MISSISSIPPI RIVER FROM OVERFLOWING INTO HORN LAKE.

The present State levee extending from the bluffs, near to and south of South Lake, along the south bank of South and Mud Lakes, and thence down Horn Lake Pass to the Mississippi River, is assumed to be sufficient to keep out the back water from th south. The new levee proposed begins at a point on this levee below Mud Lake, where the low lands along the pass appear to be narrow, thence northwest course, by the shortest line across these low lands to the ridg st of the pass, thence with this ridge in a northeasterly direction until tl st end of the North Lake is passed, thence nearly east, running as far fro e river and as near to the lake as the ground will permit, to a point about tl se-quarters of a mile below Watson's, thence in a northeasterly direction to a point below and near the Fleece place, thence due east across the bottom to the bluff. The total length of this levee is about eight miles, and is estimated to cost about ninety thousand dollars if raised four feet above high water, and provided with sufficient cross section.

The information upon which this estimate is based was not obtained fro n actual examination of the ground, but from the contour lines on the charts of the Mississippi River Survey, which are believed to be sufficient for preliminary estimates. By locating the levee near the bank of the river and utilizing private levees already in existence, it is probable the whole of the bottom lands up to the mouth of Nonconnah Creek might be protected from overflow for a sum not much exceeding the foregoing estimate; but this would expose the levee to the danger of caving into the river. A small levee to cut off North Horn Lake from the South Lake would probably cost two thousand dollars.

If Horn Lake Creek and other tributaries do not furnish water sufficient, it might become necessary to provide a culvert with a gate for the admission of water from the Mississippi River. This would probably cost about five thousand dollars; but, while there is no source from which the exact area of the water shed tributary to Horn Lake Creek can be determined, an inspection of the map of Mississippi shows it to be fifty or sixty square miles, and by a suitable arrangement of the levees twelve or fifteen square miles might be added from Cypress Creek and the Cut-Off, which would be ample for a much larger community than this.

J. H. HUMPHREYS, C. E.

December 31st, 1885.

NO. 11.

RECORD OF PRESSURE OF THE MEMPHIS WATER WORKS MADE BY CAPT. JAMES E. CLARY, C. F. D., REFERRED TO IN MAIN REPORT.

On the 20th and 21st days of this month (October, 1885), under orders issued by me, there were several fire hydrants fairly and impartially tested with an accurate and correct water pressure gauge. The days mentioned being the coolest days we have had so far this season, when little, if any, water was being used for street sprinkling and like purposes, all of which was favorable to a better pressure.

Below find amount of pounds pressure, location, date, hour and names of witnesses, viz.:

(1)

Fifteen pounds water pressure, fire hydrant corner Second Alley and Adams Street, October 20th, 2 P.M. Witnesses: Capt. P. Hackett, Capt. Jas. Ryan, Jas. E. Clary, Messrs. P. Callahan and Jere Sullivan.

(2)

Twenty-five pounds water pressure, fire hydrant corner Market and Fulton Streets, October 20th, 2:10 P.M. Witnesses: James Ryan, Jere Sullivan and C. J. Williamson.

(3)

Thirty pounds water pressure, fire hydrant corner Front Street and Bayou Gayoso, October 20, 1885, 2:30 P.M. Witnesses: Thomas Cubbins, James Ryan and Jere Sullivan.

(4)

Forty pounds water pressure, fire hydrant cor. Second and Saffarans Streets, October 20, 1885, 2:35 P.M. Witnesses: James Ryan, Jere Sullivan and Robert Stackhouse.

(5)

Thirty-five pounds water pressure, fire hydrant corner Sycamore and Fifth Streets, October 20, 1885, 2:40 P.M. Witnesses: James Ryan and Jere Sullivan.

(6)

Thirty pounds water pressure, fire hydrant corner of Alabama and alley near Quinby Street, October 20, 1885, 2:50 P.M. Witnesses: James Ryan and Jere Sullivan.

(7)

Twenty pounds water pressure, fire hydrant corner Poplar and High Streets, October 20, 1885, 2:55 P.M. Witnesses: H. M. Buford, James Ryan and Jere Sullivan.

(8)

Twenty-two pounds water pressure, fire hydrant near corner Adams Street and Yates Avenue, October 20, 1885, 3:00 P.M. Witnesses: James Ryan, Jere Sullivan and Peter Mannigan.

(9)

Twenty pounds water pressure, fire hydrant corner Washington Street and Fourth Alley, October 20, 1885, 3:10 P.M. Witnesses: James Ryan and Jere Sullivan.

(10)

Fire hydrant corner Third Alley and Adams Street, October 20, 1885, 3:15 P.M., refuses to furnish any water or pressure. Witnesses: James Ryan, Jere Sullivan and R. G. Tucker.

(11)

Twenty pounds water pressure, fire hydrant corner Third Alley and Jefferson Street, October 20, 1885, 3:25 P.M. Witnesses: James Ryan, Jere Sullivan, P. C. Peterson and Wm. Cornell.

(12)

Twenty pounds water pressure, fire hydrant corner Fourth and Jefferson Streets, October 20, 1885, 3:30 P M. Witnesses: James Ryan, Jere Sullivan and John J. Wilson.

(13)

Seven pounds water pressure, fire hydrant corner Centre Alley and Jefferson Street, October 20, 1885, 3:35 P.M. Witnesses: James E. Clary, P. H. Monaghan, James Ryan, Jere Sullivan and A. Gluck

(14)

Seven pounds water pressure, fire hydrant corner Centre Alley and Madison Street, October 20, 1885, 3:40 P.M. Witnesses: S. N. Castle, J. H. Deadrick, Jere Sullivan, James E. Clary and James Ryan.

(15)

Twenty pounds water pressure, fire hydrant corner Fourth Alley and Madison, October 20, 1885, 3:50 P.M. Witnesses: Andy Gallagher, James E. Clary, James Ryan and Jere Sullivan.

(16)

Twenty pounds water pressure, fire hydrant corner Madison and Wellington Streets, October 20, 1885, 3:55 P.M. Witnesses: James E. Clary, James Ryan and Jere Sullivan.

(17)

Five pounds water pressure, fire hydrant corner Orleans Street and Marshall Avenue, October 20, 1885, 4.00 P.M. Witnesses: John Frick, James E. Clary, James Ryan and Jere Sullivan.

(18)

Five pounds water pressure, fire hydrant in front of No. 376 Union Street, October 20, 1885, 4:05 P.M. Witnesses: James E. Clary, Jere Sullivan and James Ryan.

(19)

Fifteen pounds water pressure, fire hydrant corner Beale and Lauderdale Streets, October 20, 1885, 4:10 P.M. Witnesses: James E. Clary, James Ryan and Jere Sullivan.

(20)

Twenty-five pounds water pressure, fire hydrant opposite Gayoso Street cotton shed, October 20, 1885, 4:15 P.M. Witnesses: James E. Clary, Jere Sullivan and James Ryan.

(21)

Fifteen pounds water pressure, fire hydrant corner Third and Union Streets, October 20, 1885, 4:20 P.M. Witnesses: John Miller, James E. Clary, James Ryan and Jere Sullivan.

(22)

Ten pounds water pressure, fire hydrant corner Front and Union Streets, October 20, 1885, 4:25 P.M. Witnesses: John C. Rogers, P. Henry, I. M. Watts, S. Schloss, C. A. Denie, Clary, Ryan and Sullivan.

(23)

Two pounds water pressure, fire hydrant corner Vance and Shelby Streets, October 21, 1885, 9:50 A.M. Witnesses: James Ryan and Jere Sullivan.

(24)

Twenty pounds water pressure, fire hydrant corner Vance and Hadden Avenue, October 21, 1885, 9:55 P.M. Witnesses: Frank Venneri, Con Daly, James Ryan, James E. Clary and Jere Sullivan.

(25)

Five pounds water pressure, fire hydrant Vance Street, beyond Orleans, October 21, 1885, 10:10 A.M. Witnesses: James E. Clary, Jere Sullivan and James Ryan.

(26)

Fifteen pounds water pressure, fire hydrant corner Calhoun Street and Rayburn Avenue, October 21, 1885, 10:25 A.M. Witnesses: James E. Clary, Jere Sullivan and James Ryan.

(27)

Fifteen pounds water pressure, fire hydrant in front of cotton shed on Georgia Street, October 21, 1885, 10:32 A.M. Witnesses: James E. Clary, Jere Sullivan and James Ryan.

(28)

Seventeen pounds water pressure, fire hydrant corner South Jackson and Main Streets, October 21, 1885, 10:40 A.M. Witnesses: Jere Sullivan, James Ryan and John F. Rhodes.

As the locations above will show, I have had plugs or hydrants in different parts of the city tested.

JAMES E. CLARY,
Chief of Fire Dept.

MEMPHIS, Oct. 26, 1885.

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ORN

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0,000

4,000
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5,400

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EXHIBIT 13.

APPROXIMATE ESTIMATE OF COST OF PROTECTING HORN LAKE FROM OVERFLOW AND CONVERTING SOUTH HORN LAKE INTO A COLLECTING BASIN.

Eight miles of levees, four feet above high water of the Mississippi River	$ 92,000
Conduits and gates in Horn Lake Pass, Cut-Off and Horn Lake Creeks	12,000
Land, land damage and right of way	10,000
	114,000
Contingencies and omissions, 10 per cent	11,400
	$125,400

EXHIBIT 14.

APPROXIMATE ESTIMATE OF COST OF PUMP WELL AND ENGINE HOUSE FOUNDATION, FOUNDATIONS OF ENGINES AND BOILERS NOT INCLUDED, OF SOUTH HORN LAKE PLAN.

3000 c. y. excavation	@	$ .20	$ 600
* 40 c. y. concrete in pump well	@	8.00	320
* 679 c. y. pump well masonry	@	16.00	10,864
40 c. y. concrete walls	@	8.00	320
400 c. y. brick masonry	@	6.50	2,600
908 c. y. water table and coping	@	1.00	908
43 c. y. concrete in chimney foundation	@	8.00	344
90 c. y. stone foundation	@	12.00	1,080
344 c. y. brick masonry in shafts	@	8.00	2,752
			$19,788
Superstructure and coal houses			20,800
			40,588
Contingencies and omissions, 10 per cent			4,058
			$44,646
Two Worthington steam pumping engines (5,000,000 gallons each) and approved steel boilers, including foundation, put in place, together with all piping, connections and fittings, covering a complete engine and boiler house plant, guaranteed to achieve a duty of ninety-five million foot pounds per 100 pounds of coal			$72,000

* May be dispensed with.

EXHIBIT 15.

APPROXIMATE ESTIMATE OF COST OF SOUTH HORN LAKE FORCE-MAIN AND INLET.

59,400 lineal feet 30-inch cast iron pipe (.965 thick.) or 9236.70 tons	@	$28.00	$258,627.60
4,950 joints of gasket, (6 lbs.) 29,700	@	.02	594.00
4,950 joints of lead (60 lbs.) 297,000	@	.03½	10,395.00
Labor per joint	@	2.00	9,900.00
43,021 c. y. trenching and back-filling (5x4)	@	.30	12,906.30
			292,422.90
48-inch inlet pipe, screens, etc			4,000.00
			296,422.90
Contingencies and omissions, 10 per cent			29,642.29
			$326,065.19

EXHIBIT 16.

APPROXIMATE ESTIMATE OF COST OF DISTRIBUTING RESERVOIR, (TWENTY FEET EMBANKMENT,)—CAPACITY, 21,666,250 GALLONS, FOR SOUTH HORN LAKE PLAN.

15 acres real estate	@	$500.00		$7,500.00
6,500 c. y. mucking	@	.20	1,300.00	
27,300 c. y. excavation carried into embankment, at	@	.20	5,460.00	
17,900 c. y. embankment	@	.25	4,475.00	
78,200 c. y. reservoir embankment in 6-inch layers and rolled	@	.40	31,280.00	
15,600 c. y. puddle wall in embankment	@	.80	12,480.00	
1,100 c. y inner slope dressing	@	.30	330.00	
2,300 c. y. rubble stone slope lining 0.85 feet deep, laid in cement	@	10.00	23,000.00	
1,750 c. y. broken stone under slope lining 0.65 feet deep	@	.55	962.50	
1,600 c. y. concrete in bottom of reservoir 0.35 feet deep	@	7.00	11,200.00	
1,867 lineal feet stone coping on top of slope lining	@	.40	746.80	
1,740 square yards brick paving	@	.60	1,044.00	
172 c. y. concrete under same	@	7.00	1,204.00	
12,800 square yards slope soiling & seeding	@	.05	640.00	
2,000 lineal feet common fencing	@	.25	500.00	
1,867 lineal feet iron fence on top of embankment	@	1.00	1,867.00	
				$ 96,489.30
				103,989.30
Effluent chamber, pipes, valves, etc				19,317.00
Contingencies and omissions on $115,806 at 10 per cent				11.580.00
				$134,886.30

EXHIBIT 17.

APPROXIMATE ESTIMATE OF COST OF WOLF RIVER DAM AND CONDUIT TO PUMP WELL

Dam near crossing of the Louisville & Nashville Railway, 5 feet above low water	$26,000.00
2,600 feet brick conduit (5 feet) at $8.00	20,800.00
Gates and screen	1.500.00
	$48,300.00
Land and right of way	1,000.00

EXHIBIT 18.

APPROXIMATE ESTIMATE OF COST OF PUMP WELL AND ENGINE HOUSE FOUNDATION, FOUNDATIONS OF ENGINE AND BOILERS NOT INCLUDED, OF WOLF RIVER PLAN.

Same as Exhibit No. 10	$40,588
Contingencies and omissions, 10 per cent	4,058
	$44,646
Two Worthington steam pumping engines (5,000,000 gallons each) and approved steel boilers, including foundation, put in place, together with all piping, connections and fittings, covering a complete engine and boiler house plant, guaranteed to achieve a duty of 95,000,000 foot pounds per 100 pounds of coal	$72,000

EXHIBIT 19.

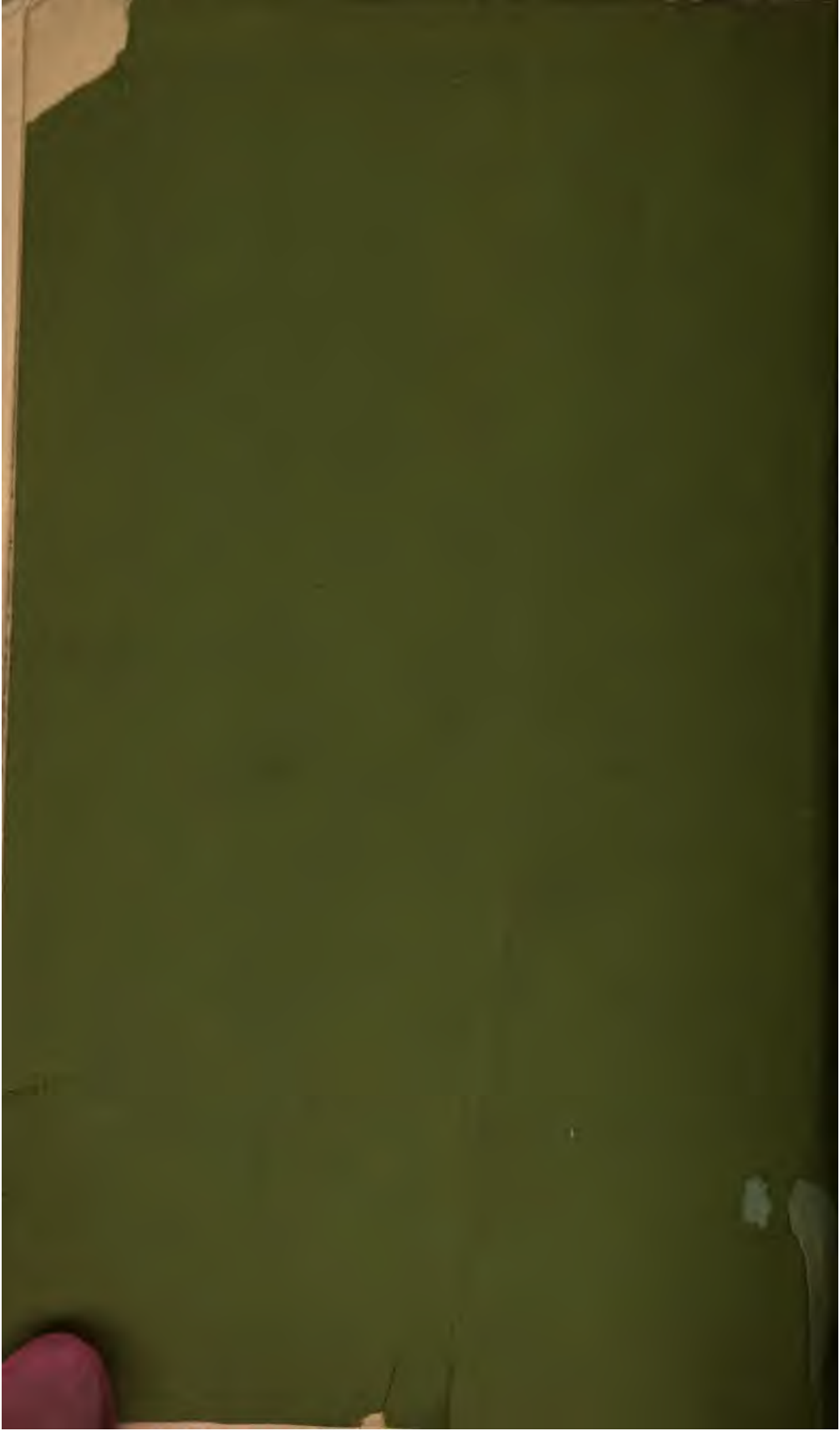
APPROXIMATE ESTIMATE OF COST OF WOLF RIVER FORCE-MAIN.

47,520 lineal feet 30-inch cast iron pipe (.965 thick) or 7386.36 tons, at $28.00	$206,818
4,400 joints, leading, gasket and labor	18,568
35,199 c. y. trenching and back-filling (5x4), at .30	10,559
	$235,945
Contingencies and omissions, 10 per cent	23,594
	$259,539

EXHIBIT 20.

APPROXIMATE ESTIMATE OF COST OF THREE RESERVOIRS TO BE LOCATED, AS DESCRIBED IN MAIN REPORT, EACH OF CAPACITY OF 52,000,000 GALLONS, TOTAL CAPACITY 156,000,000 GALLONS, (BASED ON CONTOURS AND ELEVATIONS OF THE HERMANY SURVEY)—FOR WOLF RIVER PLAN.

60	acres real estate	@ $500.00	$ 30,000
300,000	c. y. reservoir embankment	@ .35	120,000
60,600	c. y. puddle wall in embankment	@ .80	48,480
9,800	c. y. inner slope paving, brick in cement 0.75 in. thick	@ 7.00	68.600
8,500	c. y. broken stone under slope pavement, 0.066 inches thick	@ 4.00	34,000
52,000	c. y. puddle on bottom of reservoir 1.3 in.	@ .80	41,600
9,000	lineal feet stone coping	@ .40	3,600
6,000	c. y. inner slope dressing	@ .05	300
38,000	c. y. mucking	@ .20	7,600
52,000	c. y. slope soiling and seeding	@ .05	2,600
5,500	square yards brick work	@ .60	3,300
600	c. y. sand under same	@ 1.25	750
6,600	l. f. common board fencing	@ .25	1,650
			362,480
	EFFLUENT CHAMBER.		
	See Exhibit No. 16, to which 25 per cent. is added		24,147
			$386,627



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WATER COMMITTEE.

REPORT

ON A

PUBLIC WATER SUPPLY

FOR

THE CITY OF MEMPHIS,

DECEMBER, 1886.

MEMPHIS.
S. C. Toof & Co., Printers and Lithographers.
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MEMPHIS WATER COMMITTEE.

S. W. HAMPTON, CHAIRMAN.

COLTON GREENE,	C. C. HEIN,
ELIAS LOWENSTEIN,	J. C. NEELY,
WM. M. SMITH,	NAPOLEON HILL,
M. GAVIN,	JNO. OVERTON, JR.,

R. W. MITCHELL.

OFFICERS OF THE TAXING DISTRICT—MEMBERS, EX-OFFICIO.

D. P. HADDEN, PRESIDENT.

S. P. WALKER, ATTORNEY.

NILES MERIWETHER, ENGINEER.

CHAS. L. PULLEN, SECRETARY OF THE COMMITTEE.

REPORT.

MEMPHIS, December 4th, 1886.

Hon. D. P. Hadden, President,
and the Legislative Council:

GENTLEMEN—The committee appointed by you under the resolution of July 23, 1885, to consider "all matters appertaining to obtaining a bountiful supply of pure, clear, wholesome water for the use of the entire District; to take into consideration the purchase of the present water company's plant by the District, or the establishment of new water works entirely; to consider the source whence this water is to be obtained and the probable cost of same, the building of reservoirs and the probable cost of keeping same in a pure and healthy condition, and the erection of stand pipes; in a word, to take into consideration everything relative to the water question and the manner in which the financial matters shall be arranged, and the proper legislation to be obtained to carry out and consummate their views," have the honor of submitting a report of their deliberations and conclusions, together with sundry papers explaining the subject in detail. At the inception of our discussions we were confronted with the question of *ownership*. The committee felt it to be a matter of the first importance to determine whether it would be of greater advantage to the city to own its water works and exercise direct control over their management through officers to be appointed for that purpose, or to confer upon some chartered company the privilege of supplying Memphis with water. Forcible arguments were adduced on both sides, but

the committee finally reached a unanimous conclusion, and embodied their decision in a resolution, which was adopted April 16, 1886, as follows:

"It is the sense of this committee that, in view of the increasing population of the city, the construction of a system of permanent water works should be undertaken and carried out as soon as the necessary legislation can be secured by the Taxing District; and that, considering the paramount necessity for the preservation of the public health and the security and future enlargement of the system, the works should be constructed, owned and operated by the city."

Inasmuch as the Fire Department, the sewer system and the Sanitary Department of our city are under exclusive control of the City Government, and as these departments are intimately related to the water works system, and are dependent upon it for their success and efficiency, it was thought to be eminently proper, and indeed essential, to the highest efficiency of all these departments, that the water supply, as well as the other departments, should be under the full and exclusive control of the city authorities. The committee have an abiding faith that under our present compact and economical form of government there would be no increased danger of peculation, dishonesty or mismanagement by conferring on our municipal officers the additional duties growing out of a public water system. It must be conceded by all that any private corporation that would contract to supply the city with water would do so only for the measure of profit that such a contract might promise. Such a measure involves the expense for president, officers and employes, besides profit to stockholders. Under city ownership, most of this expense would be saved to the people. For many years past Memphis has received her water supply through such a corporation, and the experience has been far from satisfactory. The experience and example of all large cities in this country and others prove the advantage—yea, the *necessity* of city ownership. We may cite New York, Philadelphia, Boston,

Brooklyn, Chicago, St. Louis, Cincinnati, Nashville, Cleveland, Washington and five hundred more of the chief cities and towns of this country. Many of these have experimented with the system of private ownership, and have discarded it. It is wise to profit by the experience of others. In Continental Europe such a thing as private ownership in connection with the public water supply is not tolerated at all. Memphis has become a great commercial centre, and is a *growing* city. A well devised system of water works, supplying clear, pure, soft water in abundance, can now be established on a self-supporting basis. Every year is adding largely to our population and increasing the water consumption. It is no visionary idea to see before us the time, at no very distant day, when our water works will become an important source of net revenue, and a potential factor in the extinguishment of our city debt.

In looking for the proper *source* of supply, the committee has had under consideration perhaps every source and every plan which has ever been before our people. The driven well system, like that on Long Island, N. Y., and at Jackson, Tenn., was rejected as impracticable for local reasons. The artesian well system was rejected, because of its uncertainty and unreliability. Coldwater river, Mississippi, Tennessee river, Spring river, Arkansas, and Tuscumbia Spring, Alabama, were deemed impracticable as sources of supply because of the great expense involved in each of these plans, which was far beyond any sum that Memphis can afford to expend in this object. The foregoing being all rejected, the committee was narrowed down to Wolf river, South Horn Lake, and the Mississippi river, and to these three it has devoted close and elaborate investigation. In order to render practicable and acceptable any point from which to draw a supply of water for this great city, three conditions were

essential. The water must be sufficiently pure to be wholesome for all domestic uses; it must be abundant in quantity, and it must be obtainable at a cost not exceeding $1,200,000, that being the limit at which the system can be made certainly self-supporting, with our present population, estimated at sixty thousand. The committee has therefore sought definite and reliable information on these points in their relation to the three sources of supply last mentioned, viz.: Wolf river, South Horn Lake and the Mississippi river. Samples of water from each, taken in various stages and conditions, were sent to expert chemists for analysis. The Mississippi river was pronounced *very bad* and altogether unfit for domestic use; South Horn Lake less objectionable, but not satisfactory; Wolf river water, taken at the crossing of the Louisville & Nashville Railroad, was found to be comparatively pure, and, after precipitation or filtration, was highly approved as suitable for all domestic uses, and for use in boilers. The analytical tables accompanying this report, prepared by the Drs. Elliott, of the Western Military Institute, near Dayton, O., and Dr. Chas. Smart, United States Army, of the Surgeon General's Office, Washington, D. C., will be found interesting in this connection. This result will be a surprise to many, but when it is remembered that the Mississippi river and its tributaries drain an immense territory, extending 1000 miles from north to south and 2000 from east to west, and populated by 20,000.000 of people, with its hundred great cities, thousands of towns and villages, and countless manufactories of all descriptions, for which this mighty river performs the duty of a common sewer, no further demonstration is needed to confirm the analyses which show that its water when it reaches Memphis is loaded with foul impurities, and that it must become more so from year to year as the population of the Northwest increases. It is equally plain and credible that Wolf river,

originating from several copious springs located in a sandy district and coursing through a thinly settled country for a distance of only sixty miles to the proposed point of intake, without a town or village on its banks, must closely approximate the character of spring water when not turbid from rains, and this fact is conclusively shown by the analyses above referred to.

As to the question of supply. From the Mississippi the quantity is of course unlimited. That from South Horn Lake is somewhat doubtful. From Wolf river the discharge has been ascertained by careful measurements, taken in the autumn months after a prolonged stretch of dry weather, when the river was at its lowest stage, to be over 8,800,000 gallons per hour, or thirty-five times more than the daily consumption of Memphis at this time.

In considering the question of cost, it was ascertained that the expenditure would be about the same in obtaining water either from South Horn Lake or from Wolf river at the point proposed. But on account of the changing current of the Mississippi and the consequent unreliability of its banks, the committee found that any plan for taking a sufficient supply of water from that source would involve engineering problems which have never yet been solved, and would entail an expense necessarily very great. So serious were these difficulties that there was not sufficient time or means at the command of the committee to justify them in undertaking the preliminary examinations and surveys which were necessary in order to determine the mere practicability of the scheme.

With these facts ascertained, the committee has been led almost irresistibly to the conclusion that Wolf river offers the true solution of the water question for Memphis. In common with the mass of our citizens the members of the committee, at the time of their appointment, were strongly antag-

onistic to Wolf river water. They knew it only by the supply that had been daily dealt out to them by the present water company for years past, and which was taken from the river at the present location of their works, only a short distance above its confluence with the Mississippi and with Bayou Gayoso, liable at all times to be contaminated by backwater from these streams, and also receiving the foul drainings from the northern portion of our city. In the progress of its work the committee soon discovered that this was altogether a different water from that from Wolf river above the railroad crossing, where it is entirely beyond the reach of the contaminating influences above referred to. It is the water taken from this higher point that shows such satisfactory results under analysis, and it was here that the stream was gauged during its lowest stages and showed an hourly discharge of 8,800,000 gallons. Deriving its source from several copious springs, it reaches the point referred to in a condition of almost original purity. The quantity of minerals or other foreign substances contained in it is remarkably small. It is free from lime and is therefore very soft and specially adapted for use in laundries and boilers. The principal objection is the color imparted to the water from the clay soil of the country through which it flows. After heavy rains this is particularly noticeable and objectionable. But after the rains cease the abundant flow of clear water from above soon carries off the turbid current and cleanses the stream again. With ample reservoirs the pumping might be so regulated as to avoid taking the water while in its muddy condition, and thus the public supply might be kept comparatively clear. But to secure certainty on this score the committee have been engaged during the last six months in investigating the Hyatt filter, an invention of recent years, designed especially for filtering water in large quantities for the use of cities and towns. The

assistance of skilled experts of national reputation in such matters was called in, and with their help an exhaustive examination of this filter has been made. After several very important improvements which were suggested and adopted during the examination, the filter has been pronounced a success by the experts, and the proprietors guarantee satisfaction in its work. By its adoption one or more of the reservoirs can be dispensed with, which would otherwise be required, and thus will be secured a net reduction in the cost of the plant together with increased net revenue, while at the same time we remove the stain and impurities which the river receives during the rainy spells; thus the works can operate continuously, and yet, by means of the filter, can supply clear, pellucid water at all times.

From the accompanying papers it will be seen that the estimated cost of the Wolf river plan, (including the filters and high-service plant), will be $952,000. Based on the experience of the present water company, the estimated revenue from water rates will exceed $120,000 the first year.

The cost of maintaining and operating the works will be $48,000, and the interest on cost, at five per cent., will be $47,600, making a total expenditure per annum of $96,000, and leaving a net revenue, over and above all expenditures, of not less than $24,000. This gives us at the outset a self-supporting water system; and the figures on which it is based are believed to be conservative and within the line of safety rather than beyond it. With the security that such a water plant and its revenues affords to investors it is believed that its bonds can be negotiated readily at five per cent, without any additional guarantee. But to "make assurance doubly sure," and to place these bonds at the very top of the list, the committee suggested that it might be the part of wisdom to levy a light tax for the first few years in order to provide

a *certain* fund to meet the interest or to protect the interest from any possible deficit of revenue. Such a provision, we have good reason to believe, would enable the city to negotiate the bonds at not exceeding four and one-half per cent. This would effect a saving to the city of some $4800 per annum on interest alone, and would to that extent increase the net revenues. At the end of two years after the works are once in full operation it is believed that their success will be so fully established that the tax will no longer be required. In the meantime, while on one side the tax is being collected from the people, it will on the other side be more than returned to them in the reduced cost of water and the enhanced value of their property.

It is now, therefore, a well established fact that Memphis has within her reach a water supply far superior to the celebrated Croton system of New York in quantity, quality and accessibility. The adoption of the right system will secure for our city a superabundant supply of clear, pure, soft water, with sufficient pressure to carry it freely to every point within the corporate limits, and to furnish power for running elevators of hotels and business houses, and also for operating light manufacturing establishments in any of the upper stories of buildings in the business portion of the city. By the use of a high pressure service in connection with a system of hose carriages, the efficiency of the Fire Department may be very much promoted in that part of the city embraced within the high-service limits.

A detailed description of the machinery by which these important results will be obtained accompanies this report.

All these results, and others of great value to our people, the committee believes, will be attained by the establishment of a system of water works, to be owned and operated by the

city in accordance with the plans described in the accompanying papers.

To Gen. Colton Greene, of this committee, his associates committed the burden of the work. His knowledge of engineering and sanitary science eminently fitted him for the task, and the fidelity with which he has accomplished it is attested by the results which are herewith submitted.

The committee have, in conclusion, adopted the following:

WHEREAS, An abundant supply of pure water is absolutely essential to the health of our people, the safety of our property, and the general welfare of our city; therefore

Be it resolved by the Water Committee of Ten, That we urgently recommend the Legislative Council of the Taxing District to take immediate steps to secure the passage of a law at the next session of the Legislature authorizing the government of this Taxing District to build and operate a public system of water works; to issue bonds secured by the plant to pay for the same, and to secure such additional legislation as may be needed for the successful accomplishment of the object.

Resolved, further, That we recommend Wolf River, at a point above and near to the L. & N. R. R. crossing, as the proper source of supply; and that we advise the adoption by the Legislative Council of the plan for a system of water works as described in the reports made to this committee by Gen. Colton Greene, the details and particulars of which are embodied in the accompanying papers.

S. W. HAMPTON.
COLTON GREENE.
E. LOWENSTEIN.
C. C. HEIN.
JNO. OVERTON, JR.
M. GAVIN.
R. W. MITCHELL.
WM. M. SMITH.
J. C. NEELY.

GENERAL GREENE'S REPORT.

MEMPHIS, TENN., December 1, 1886.

To the Water Committee:

GENTLEMEN—By resolution of the committee passed April 3, 1886, the consideration of those parts of the report which the writer had the honor to submit February 23, 1886, (see pages 27, 28, 39, 40, 41, 44, 45 and 47), relating to South Horn Lake as a source of public water supply and the Hyatt method of filtration, was adjourned for further investigation, to be conducted with the aid and counsel of such men of exact science whose recommendations would stand for trustworthy opinions, free from local influences, interests and prejudices. This report, therefore, is founded on the opinions of the experts employed, and is intended to present the question for the final determination of the committee.

The inquiry into the sanitary question involved in the proposed plans for the use of South Horn Lake, was conducted by Dr. Charles Smart, Surgeon and Major United States Army, an experienced sanitary analyst, recognized as one of the foremost authorities on public water supplies in their relation to public health. Primarily, his investigations concerned the water of the Lake, but since it is only by taking a mean of many experiments under identical circumstances that results exactly consistent can be reached, it was necessary to analyze the waters of the Mississippi and Wolf rivers and the Pass, as well as of the Lake. The analyses of these waters were begun April 3d, and continued at intervals to October 6th, 1886, as shown in the synopsis to Dr. Smart's report, which also embraces others made by him in 1879 and

1880 for the National Board of Health. The samples for examination were collected under direction of the writer by Capt. Jas. E. Cleary, Chief of Fire Department, and the steamers of the Lee Line and the steam tugs of Messrs. Brown & Jones (in charge of Mr. Robert A. Speed), which were voluntarily placed at his service by their owners.

Dr. Smart's report, which is now submitted to the committee (Appendix A) presents an exhaustive review of the subject, and, aside from its practical value to Memphis, is a useful and important contribution to the literature of sanitary science. The proposal for admitting the water of the Mississippi river by the Pass into the Lake is condemned. It is shown that the water of the river, above the mouth of Wolf river and the Pass, is generally loaded with organic matter; that the inflow into the Lake takes place only during the periods when the river water has a high degree of impurity; and that, notwithstanding purifying changes would take place in its passage and the water be diluted by the better water in the Lake derived from the water shed, the sewage inflow involves so much danger to the public health that any suggestion for the use of the river water should meet with an earnest protest. Nor is the plan for excluding the river water from the Lake and relying solely for the supply from the water shed approved. It is thought probable that the waters from the local drainage area are "much superior in quality to that of the Mississippi river, and that in progress of time, after the reclamation of the lands now subject to overflow, an excellent water supply might be obtained from these sources; but it is feared that the extensive changes in the character of the bottom lands that would attend and follow the attempted reclamation would develop malarial influences that would pervade the waters of the Lake for a continued period, and necessitate a thorough filtration for their removal."

In view of these opinions it was thought inexpedient to investigate this branch of the subject further, and examinations of the water of Wolf river, near where it is crossed by the Louisville and Nashville Railway, about forty-five miles (reckoned by its sinuosities) above its mouth, were entered on for determining its quality and condition when filtered by the Hyatt method.

The results obtained from these examinations are exhibited in the analyses numbered 11, 12, 13, 14, 15, 16 of Dr. Smart's report.

Since the main inquiry at this point was for resolving the utility and efficiency of the Hyatt filter for clearing the water when in its worst condition, five gallons of it were collected September 16, 1886, directly after a beating and heavy rainfall of several days' duration, when the river was swollen and filled with driftwood, and the water more turbid than it had been observed in many years. This sample was sent by Capt. Cleary to the writer in New York, one part of which was filtered by the Hyatt method. Equal parts of the natural and filtered water were then sent to Dr. Smart, at Washington, for analysis, corresponding to the two bottles that are now exhibited to the committee, which were sent back to Memphis.

The filtered water, as will be noticed, is clear and pellucid; the natural water muddy and repulsive to the sight. The test was crucial. The natural water contained 146 parts of solid matter in 100,000, of which the filtration removed 77 grains to each gallon—or 27,500 pounds to 2,500,000 gallons, the assumed daily work of a 30-feet filter. It is not to be understood, however, that the water would be pumped for the public supply while in this anomalous condition, as this experiment was employed only to test the efficiency of the Hyatt process of filtration.

"From these examinations," says Dr. Smart, "it appears that the water of Wolf river, though extremely unsightly in its turbid state, is an excellent water when its suspended matters have been removed. It contains only about eight grains of dissolved saline substance per gallon, and the organic ammonia distilled from it falls within the arbitrary limits of wholesomeness adopted by most sanitary authorities; * * * and if filtration be effected and a clear water furnished, that clear water will be of a satisfactory quality for all the purposes of a municipal supply. This was demonstrated not only by the present analyses, but by several made in 1879. * * * If the Hyatt filter can accomplish the filtration, so far as the demands of quantity are concerned, the writer (Dr. Smart) is confident that the filtered water, if clear, will be of a satisfactory purity. * * * And, besides removing the suspended matter and yielding a clear water for domestic and manufacturing purposes, the filtration may be confidently expected to free the water from all suspicion of malarial contamination. * * * Small streams are obviously better than large streams as a source of supply, because the area drained by them may be more effectually guarded against dangerous contaminations. An efficient supervision is the only known preventive of the invasion of typhoid by the water supply. With such a care exercised over the radicles and course of the Wolf river, and the subsequent filtration of the water as proposed, a pure and healthful supply may be obtained for the city of Memphis."

FILTRATION BY THE HYATT METHOD.

The filter-plant proposed by the Newark Filtering Company for clearing the water of Wolf river, described in the report of February 23, 1886, has since that date been recommended for filtering the public water supply of Washington, D. C. The examination of the works and method in this

instance was trusted to Captain T. W. Symons, Corps of Engineers, U. S. A., by Major General John Newton, Chief of Engineers, in pursuance of a resolution of the United States Senate (February 8th, 1886—Ex. Doc. No. 154). The recommendation was for a plant capable of filtering 40,000,000 gallons per twenty four hours, and it is believed that an appropriation for carrying out the plan will be made by Congress during its approaching session. Similar works are now in successful operation in Somerville and Brunswick, N. J.; Charleston, W. Va.; Belleville, Ill., etc., and others are being erected in other cities.

The writer's own examinations and observations of the plan, extending over a period of fifteen months, had satisfied him of its efficiency, yet since there had been no experience for determining its adaptability to the needs of Memphis, he required further demonstration. To this end the filter was subjected to the extreme test of the turbid water of Wolf river, as has been related, and the determination of the mechanical and hydraulic capabilities referred to Mr. J. J. R. Croes, C. E., and Mr. A. A. Willson, M. E, of New York, engineers of established reputation and high character, who, it may be remarked, began the examination with characteristic professional distrust of innovations.

Their reports are herewith submitted (B and C of Appendix) with the plans and specifications for the Memphis plant proposed by the Newark Filtering Company (D, E, F, G, H, I of Appendix), who are to guarantee its efficiency and are to receive no compensation until its success has been demonstrated. This plant differs from the Washington plan mainly in respect of the method employed for washing the filter-bed, and consists of three cylindrical open iron tanks, twenty feet high and thirty and one-quarter feet in diameter, each containing a filter-bed of sand and coke six feet deep; an appa-

ratus for feeding the coagulants; stand pipe; wrought-iron well 100 feet deep and five feet in diameter, and the required pipes, valves, grates, etc., all of which are fully set forth in the specifications. The proposal embraces the aeration of the water, and the guaranteed daily service is for 7,500,000 gallons, filtered.

Mr. Willson in his report expresses the opinion that "the general design and arrangement of the details of this filter-plant are excellent, and that he can see no reason why, in a mechanical point of view, the whole plant should not operate practically." He approves the devices for supplying the coagulants and for aerating the water, "if they are properly designed;" determines the increased cost of filtration, etc., etc.; makes valuable suggestions for improving the minor parts, and though expressing a qualified approval in some respects, concludes that he cannot see why, "should this filter be adopted at the Memphis water works, it would not prove an entire success," and "would therefore recommend that the Water Committee adopt this plan of filtration." It is Mr. Croes' opinion that the "capacity of filtration of a given area (by the Hyatt method) is about seventy-five times what is possible by a simple filtration;" that "although the aeration of the filtered water" may not "produce the oxidation necessary to preserve the water pure for any length of time," it "will unquestionably be of some benefit. The washing from below in sections of one-quarter of the area at a time, appeared to me, (him) on examining its operation, to be exceedingly effective," but he thinks it will be necessary in order to secure the high rate of filtration guaranteed, "to so arrange the tanks that a head of at least fifty feet can be put on the filter," which "would increase the annual cost of pumping about $2700 above Mr. Willson's estimate;" agrees with Mr. Willson that three per cent. of the water pumped will be consumed in

washing the filter bed, and says in conclusion, "I am of opinion that the general plan of filtration proposed is entirely practicable and will be economical, and I recommend its adoption."

It has already been shown (report, February, 1886,) that the water of Wolf river, below Raleigh, was expressly condemned for domestic use, and it was recommended that the public supply should be taken from a point near where the Louisville and Nashville Railroad crosses the river, for economic reasons. Detailed estimates of approximate cost, expense and revenue were submitted and a general plan proposed (pages 44, 45, 46). It was then suggested that a high-service supply was not yet needed, but the increasing growth of the city, as it appears to-day, seems to indicate that this provision should be made, and doubtless other changes of the plan will be found expedient when the work shall be placed in the hands of the Chief Engineer.

In the business parts of the city, where the levels are high, the pressure from the proposed reservoir would vary from twenty-eight to thirty-six pounds. It is proposed to increase this pressure to sixty-five within the area extending from Exchange street south to the city limits, and lying between the Mississippi river and the alley east of Second street, thence by Mulberry street south, by means of an iron reservoir or tank, supported by a Water-Tower, to be located adjacent to the proposed distributing reservoir, this area to be supplied by a separate main connecting with the general system of pipes (cut off by stop gates), to provide as safeguards for reinforcing each other. The Tower is to be constructed of brick and stone, of a height to raise the flow line eighty-five feet above the distributing reservoir. The tank (30x32 feet) is to have a capacity of 140,000 gallons, and is to be supplied by pumps capable of lifting 1,500,000 gallons

in each twenty-four hours. The cost of the whole plant will be, approximately, $30,000, and the men in charge would be also employed to operate the Filters. The increased expense of maintenance and interest would be compensated by a greatly increased revenue. The pressure to be afforded will lift the heaviest elevators to be employed, bring into use motors and turbines for operating light machinery for manufacturing, and make the now unused upper floors of buildings tenantable, while the waste water resulting from these sources might be utilized for flushing the sewer pipes; and, finally, this pressure would greatly increase the efficiency of the Fire Department and diminish its expense.

The object of these investigations, which have proceeded over a period of sixteen months, was to determine upon a plan of water works for the city of Memphis that would be permanent; to obtain a clear, pure, wholesome and abundant supply of water, and to devise ways and means whereby the works would be constructed, owned and operated by the city without imposing a burden upon the public more than the water rate now paid. The investigation is now concluded, and a summary of the plans that are proposed and recommended is now submitted for the action of the committee.

SUMMARY.

1. It is proposed to establish a Pumping Station, or buildings to accommodate the pumping machinery, engine, boilers, coal houses, etc., at a suitable point near where the Louisville and Nashville Railroad crosses Wolf river, from which the public supply is to be taken.

2. The water is to be delivered through one line of cast iron pipe thirty (30) inches in diameter, which is to follow the contours of the surface to the distributing reservoir.

3. The Hyatt Filter-plant is to be located at the end of the force main directly at or near the embankment of the distributing reservoir.

4. The High-Service Tower is to be similarly located.

5. The Distributing Reservoir (capacity 21,666,250 gallons) is to be located on the west side of the Hernando road between McLemore and Richmond avenues, south 27½°, east 13,050 feet, or 2 47-100 miles from the center of Court Square.

6. The water pumped from the station is to pass through the Filters and delivered in the Distributing Reservoir, filtered and aerated.

7. The general supply will be delivered by gravity from the Distributing Reservoir. The High-Service supply will be delivered from the reservoir in the Tower. Each service is to be provided with its own supply main and distributing pipes, connecting with each other and cut off by stop gates.

The cost of the plant will be.....	$692,000	
Of the distributing pipe system.....	260,000	$952,000
The annual revenue from water rates (first year) will be.....		120,000
The annual cost of maintenance will be	$ 48,400	
The annual interest at 5 per cent. on the cost of plant will be.....	$ 47,600	$ 96,000
The revenue (first year) in excess of maintenance and interest will be.....		$ 24,000

COLTON GREENE.

APPENDIX.

[A]

DR. SMART'S REPORT.

WASHINGTON, D. C., Oct. 20, 1886.

To General Colton Greene, Memphis:

GENERAL—I have the honor to report that during the past summer I have made a series of analyses of waters transmitted from Memphis for examination. These include water from the Mississippi above Memphis, from the same river near the mouth of Horn Lake Pass, from the Pass mentioned, from South Horn Lake, and from Wolf river at the crossing of the Louisville and Nashville Railroad.

The Mississippi water was forwarded with the view of determining whether the sewage of Memphis influenced the quality of the river water at a point twenty-six miles below, following the sinuosities of the stream, where it communicates with the basin of South Horn Lake. The daily outflow of sewage from a city like Memphis consists of a volume of liquid foulness capable, one would suppose, of conveying an appreciable contamination to a stream as large even as the Mississippi. But the outflow is gradual into the onward flow of the river, and the consequent dilution, when diffusion has taken place, is more than homœpathic in its immensity. If the river contained an organically pure water prior to the introduction of the sewage, the detection of the latter, within certain limits of dilution, would be an easy matter; but the Mississippi at Memphis is generally loaded with organic matter washed down from its extensive water shed, and in this the general impurity of the river, the sewage of the city immediately becomes lost. The most careful and delicate observations on the water above and below the point of inflow would be required to show that the one had a greater or less impurity than the other.

Moreover, for the detection of sewage, the experiment must be conducted on the freshly collected water. Sewage is evanescent; its nitrogenized matters speedily revert to the

inorganic condition, leaving but little trace of their origin. Hence, when waters from the Mississippi above Memphis and at the mouth of Horn Lake Pass were forwarded for analysis, it was impossible to determine on their arrival at Washington whether either of them contained undecomposed sewage at the time of its collection.

Four samples of the Mississippi water were examined—two taken on May 4, one from above the city and the other twenty-six miles below, and two taken from above the city on July 21, one at a depth of ten feet and the other at twenty feet below the surface, the United States gauge at the city reading 13.8 feet.

All these waters were unfit for potable use, not alone from their turbidity, but from the large amounts of nitrogenous organic matter which they contained. The results of the analyses corresponded in general terms with those of the same water made by the writer at Memphis in 1879 and with a series of analyses of the river water from New Orleans, La., made in 1880 and 1881.

River waters vary in quality according to the height of the stream. When the river is low there is usually a tendency to the deposition of suspended matter; when high, the surface washings of the water shed are swept into the current, the increased flow of which prevents their deposition and the consequent purification of the water. High water, therefore, corresponds with the period of maximum impurity. At such times the Mississippi water is loaded with fine particles of sand, clay and vegetable detritus, in addition to the dissolved organic matters which are usually present in surface waters. Sedimentation for a few days readily clears the water of its suspended matters, and the process of oxidation and nitrification that are going on during this period destroy much of the dissolved organic matter. The Mississippi water may, therefore, be easily obtained on the small scale, clear, colorless and comparatively free from organic matters, so far as chemical analysis is competent to detect their presence. Sedimented for three days, the turbid water of the Mississippi at Memphis gave as good laboratory results as the Croton

water supply of New York, the Washington supply from the Potomac, or the Richmond supply from the James river.

The engineering and financial difficulties that lie in the way of a water supply for Memphis direct from the Mississippi are so great as to put any scheme of this kind out of consideration. But as the water of this river by its inflow through Horn Lake Pass, when the Memphis gauge is over thirteen feet, contributes to the supply of South Horn Lake, a consideration of the quality of the Mississippi water is needful in connection with the proposed use of the Lake as a water source of the city.

Two points, both already incidentally referred to, require notice as bearing on this subject, and both lend their weight against the advisability of admitting the Mississippi water into the suggested supply: 1, the generally impure character of the water, and, 2, its special contamination by sewage. Analyses have shown that the impurity of the river is proportioned to its turbidity; and the latter manifestly depends on the height of the stream and the rapidity of its flow. In fact, as already stated, the season of high water in a river is that of its greatest impurity; and it is precisely at this period that the greatest inflow into South Horn Lake would take place were the river water not excluded from the basin. Of course, in the Pass and Lake, deposition would go on, and purifying changes take place which would tend to improve the quality of the water; moreover, the inflowing water from the river would be diluted with the better water contained in the basin; for if the latter do not contain a better quality of water than the river in the high stages, it is unfit for use as a supply for the city. As bearing on the quality of the river and Lake supplies, three samples were examined—one from the river near the mouth of Horn Lake Pass, one from the Pass and one from the center of the Lake. These specimens, collected, the first in January and the others in February, were not transmitted until April. They do not, therefore, represent the waters as they would be distributed for use fresh from their source, but as altered by storage for two or three months under conditions which chemical analyses

have shown to be not unfavorable to the natural processes concerned in the reduction of organic matter to the inorganic state. Nevertheless, as the three waters remained under similar conditions for about the same length of time, a comparison of their relative purity on analysis promised to throw light on their relative purity at the time of their collection. The water from the river at the mouth of the Pass (No. 8 on the tabular statement appended to this report) showed to advantage compared with the river samples that had been examined without undergoing the process of storage, although the stream was high at the time of its collection. The organic ammonia was reduced to .024 and the oxygen required for the destruction of its organic matter to .225 per 100,000; but the amount of free ammonia, .020, with the trace of nitrites, indicated that the natural purifying processes were still in operation. The water from the Pass (analysis 9) was infinitely superior to that from the river, for although the same amount of oxygen was required, the free and organic ammonias measured only .004 and .0095 parts per 100,000, respectively. That from the Lake (analysis 10) was further improved by the total disappearance of the free ammonia and the reduction of the organic ammonia to .0075, results which bring this sample within the limits of wholesomeness, as those limits are usually accepted by sanitary analysts. It is impossible to predicate from these results the actual condition of these waters at the time of their collection; but they show definitely that the water in the Lake, and hence that from its local water shed, contained originally a less quantity of organic matter, or what is less likely, a more readily destroyed organic matter, than the inflow from the Mississippi river.

This opens up the question of the nature of the organic matter in the river water. One of the chief points in the sanitary analysis of a water used for dietetic purposes is the detection of any sewage inflow that may be present. This has frequently been effected in the case of polluted wells and cisterns where the dilution is limited. Here the results are invaluable because they call for such a survey of the surroundings of the water supply as will expose the source of

the sewage contamination. Were the polluted inflow recognizable on inspection, chemical analysis to determine its presence would be unnecessary. The detection of human excreta in a river water is a matter of greater difficulty on account of the pre-existing impurity of the stream, the extent of the dilution when diffusion has taken place, and the rapidity of the changes due to mechanical, chemical and vital agencies during the progress of its flow. But, if in the case of wells and cisterns, chemical analysis be needless when the polluting inflow is manifest, it is equally needless under similar circumstances, in the case of a river water. The well is condemned unhesitatingly by sanitary authorities and chemists, and the same rule ought to hold with regard to the polluted river. The small amount of capital invested in a dangerous well frequently protests against its abandonment on the ground that the water has been used for a long period without having caused injury to its consumers. The dangerous character of such a well consists in what its waters may do, not in what they have done. It is well known that small quantities of sewage from a healthy human system may be present in a water without injuriously affecting those who may use it; and further, the filtration to which the sewage is subjected in its progress to the well frequently exercises so powerful an influence on the organic matters that they are completely destroyed, and are recognized in the water only by the harmless inorganic constituents with which they are associated, or into which they have been transformed, such as chloride of sodium, or ammonia, or even by the nitrates, into which the latter is ultimately converted. A water of this character may be used for years with impunity. But all sewage matters do not come from the healthy human system, and observation and experience have shown that the fœcal excreta of some specific diseases contain the contagia of those diseases, and that these, instead of being destroyed like the organic matters of healthy depositions by the agencies at work during filtration, are capable of resisting these powerful influences and of entering the well in full possession of all their powers for evil. A well or cistern is dangerous, therefore,

not because sewage enters it, but because an infected sewage may enter it. In this country typhoid fever is the most dangerous and prevalent disease which is thus propagated. Its attacks are often insidious, and wells having a sewage connection frequently become infected and form the center of a local epidemic, the first cause of which may remain unknown.

Although a well water may contain sewage yet be harmless save as to future possibilities, a river water which contains sewage must always be regarded as a source of present danger when used as a drinking supply. The contributors to the sewage inflow of a river are so numerous, and typhoid fever so continually and extensively prevalent, that the outflow from the sewers of a populous city cannot be safely assumed to be uninfected. The fact that the sewage of a city enters a river above the point suggested as the intake of a water supply should suffice to set aside the proposition, irrespective of chemical analysis or any other considerations. The capital invested by certain municipalities and corporations in introducing and maintaining a general water supply from a sewage-polluted river interferes with practical action based upon these considerations. It has been urged that sewage is harmless, as evidenced by the long-continued use of sewage-polluted wells; and that the purification by the natural processes taking place in a running stream suffice to remove or destroy the sewage after a course of a few miles, so that the most delicate method of chemical analysis fails to detect its presence. The fallacy of these arguments may easily be understood from what has been already said. It is not the excrementitious matters of health that are dangerous, but those that contain the contagion or germs of a disease; and although the organic matters of healthy sewage may be deposited or decomposed into inorganic substances in their progress with the onward flow of a river, there is no evidence that the contagion of typhoid fever is destroyed in this manner. On the contrary, since the powerful influences operating during the process of filtration through the soil into a well fail to destroy the typhoid contagion, although capable of reducing non-specific organic matters to the inorganic

condition, it is inconceivable that the weaker influences, which, operating in a running stream, fail even to remove the non-specific matters, should be efficient in destroying the less destructible contagion.

Typhoid fever may often be traced in the circuit of an infected well water supply; but it is more difficult to recognize its propagation by sewage in an extensive system of municipal supply. This difficulty originates in the fact that a transmission by the drinking water is not the only means by which typhoid fever is propagated. The disease may arise *de novo*, according to some observers, taking its origin in certain obscure exhalations from soils that have less moisture in them than those which exhale a malarial or paludal influence; it is directly contagious according to others, although this is not a general belief; it is indirectly contagious by means of clothing or other articles soiled with the excreta of an infected person, or by exhalations from soils or sewers which are charged with infected discharges. Hence, when a case of fever occurs in a certain locality from a transmission by the water supply, secondary cases may spring up around it and obscure the testimony as to the propagation of the disease by the sewage-polluted water. Thus it may be shown by municipal statistics that the fever does not prevail specially along the lines of a systematic water supply, but is generally distributed over the city. Again, there are few cities in which well water is not used to some extent, particularly in the suburbs; and other municipal statistics may show that the fever prevails less in the line of a systematic supply from a river which contains sewage than in the suburban districts, but this merely shows the influence of concentration in well water as compared with the dilution of the contagion in the large and ever-changing volume of the river.

But although it is difficult to trace the propagation of typhoid fever in a city to the use of a river water containing sewage, it is interesting and instructive to know that those cities, which obtain and preserve a pure supply by a careful selection of a drainage area and a vigilant guard against its contamination by sewage, have a remarkably less death-rate

from typhoid fever than those that are careless in this respect and make use of a river water into which the sewage of the upper settlements flows without restriction. Brooklyn on Long Island has perhaps the best water supply of any city of this country. All of its wells have been closed and the general supply is protected from the inflow of sewage. During the past ten years this city had an average annual death-rate from typhoid fever of a little over 15 in every 100,000 of its inhabitants. New York, which derived its supply from a larger area than Brooklyn, and which in consequence experiences a greater difficulty in preserving that area from contaminating influences, had an average annual rate of 26 during the decade. London, England, had a rate of 28; and here also every effort is made to preserve the water supply in a state of purity. In cities known to have a sewage inflow into the rivers which furnish their water the rates are higher. Boston, which acknowledges a somewhat contaminated supply, had a rate of 38; Cincinnati, supplied by the Ohio river, 63; Philadelphia, by the Schuylkill, 66; and so for others. The medical history of Baltimore, Md., presents a striking illustration of the decrease of deaths from this fever, following the closure of sewage, polluted wells, and the introduction of a free supply of water from an area susceptible of being well protected from dangerous contaminations. Its rates fell from 80 and 94 in 1866 and 1867 to 42 during each of the past two years; from an annual average of 78.3 during the decade 1866–75 to 52.5 in the past decade. But perhaps the city of New Orleans, La., furnishes the most noteworthy evidence of the connection between typhoid fever and sewage in the water supply by showing that with many unsanitary conditions, due to peculiarities of site and generally regarded as strongly provocative of the spread of typhoid, there are fewer deaths from that fever—24.6 as the average annual rate of the past decade—than in the cities of New York or London. The water supply is mainly derived from the rainfall, collected and stored in cypress-wood cisterns which are preserved from all possibility of sewage contamination by being considerably elevated above the surface of the ground.

These facts, although complicated by many disturbing elements, suggest the likelihood that typhoid fever in a municipality, other things being equal, is proportioned to the sewage inflow into its water supply.

Moreover, there is a well developed seasonal tide in the prevalence of this fever which spreads its maximum in the United States over the latter half of the third and the first part of the last quarter of the calendar year. Dr. Baker, Secretary of the State Board of Health of Michigan, has shown that in his State this increased prevalence follows a low stage of water in the wells, when sewage inflow is less diluted than at other seasons. But the same period of prevalence holds good in cities that have a general water supply from unguarded rivers, corresponding with the time when the sewage inflow into the streams is in like manner undiluted.

These considerations point strongly to the danger of utilizing as a water supply a stream which has been the recipient of sewage matters, and should suffice to condemn on behalf of the public health any plans looking to its introduction. There is, however, in the history of recent epidemics, positive evidence of the danger to a community from the contamination of a running stream by the typhoid contagion. The experiences of Plymouth, Pa., are fresh in the memory of the sanitarians and medical men of this country.

It remains to be remarked that a water once contaminated by sewage is always dangerous, as there is no known method save on the small scale by boiling of destroying the contagion that may be present. Sedimentation and filtration remove suspended matters and give a clear and seemingly pure water. Filtration through a good soil or filter-bed of special materials will destroy ordinary organic matters, reducing them to harmless inorganic compounds, and the same results take place, though by far less rapidly, in the current of a running stream; but the dissemination of typhoid fever by the waters of wells and springs that had been subjected to the most efficient natural filtration demonstrates the inability of this process to free the water from the contagion of that dangerous disease. The inefficacy of sedimentation in this respect is not

so clearly defined, but it has not been shown that a sedimented water is free from danger.

From what has been said the undesirability of admitting the Mississippi river water into South Horn Lake as a part of the Memphis supply may readily be gathered.

1. The water of the river as shown by analysis is generally loaded with organic matters, and seldom so free from such matters as to satisfy the requirements of the best knowledge of sanitary science; moreover, the inflow into the Lake takes place only during the periods when the river water has a high degree of impurity.

2. And chiefly, the sewage inflow into the river involves too much of danger to the public health to admit of any suggestion or recommendation other than an earnest protest against the use of the river water in any plan looking to the supply of Memphis.

What the character of the water of the South Horn Lake may be when fresh and free from the turbid inflow from the Pass cannot be determined from the specimens sent for analysis. It is probable that the waters of the cut-off, Horn Lake Creek and the springs from the local area of drainage are much superior in quality to that of the Mississippi river, (compare analysis 10 and 8), and that in the progress of time, after the reclamation of the lands now subject to overflow, an excellent water supply might be obtained from these sources; but it is feared that the extensive changes in the character of the bottom lands which would attend and follow the attempted reclamation would develop malarial influences that would pervade the waters of the Lake for a continued period, and necessitate a thorough filtration for their removal. The report of the Memphis Water Committee, February 23 of this year, in treating of the South Horn Lake supply, does not refer to filtration as a part of the project, the water being assumed to have clarified itself by sedimentation in the Lake and in the distributing reservoir. In view, however, of malarial possibilities from the immediate surroundings of the Lake, filtration appears to be a sanitary necessity. No systematic effort has yet been made to filter a surface water with a view specially

to the removal of the germs of malarial disease, but it is well known that only surface waters transmit the paroxysmal fevers, and that communities that have been scourged by these diseases have been comparatively healthful on the substitution of a deep well water, that is, a water thoroughly filtered by natural process, for that from ponds and sluggish streams fed by the drainage of marshes, swamps and jungles.

A special means for aeration is mentioned in the committee's report in connection with the supply from South Horn Lake. The aeration of a water certainly tends to purify it from readily oxidizable organic substances, but there is no experiment nor observation to indicate that the malarial poison, which is manifestly the chief source of danger in the supply from this source, is in any way affected by exposure to air. On the contrary, the natural history of the malarial poison shows the persistence of its pernicious influence, even when fully exposed, by dissemination or diffusion to the oxygen of the atmosphere.

Four samples of the water from Wolf river were received for examination, all taken from the stream at the crossing of the Louisville and Nashville Railway. One was collected November 15, 1885, and permitted to stand uncorked in the original bottle for nine months, or until August 12, 1886, when it was carefully decanted for examination from the precipitate of clay and flocculent matter which formed a layer about a quarter of an inch in depth at the bottom. A second, collected August 11, 1886, was filtered through a common stone filter and immediately transmitted for examination. The third and fourth specimens were collected September 16, 1886, and forwarded to New York, where one of them was filtered by the Hyatt process; both were shortly afterward sent to Washington for examination.

The value of the filtration through the common stone filter does not appear on analysis, as the results differ but little practically from those formerly obtained by the writer from Wolf river water which had undergone no process of purification. (Compare analysis 12 with 23 and 24.)

The water stored for nine months and subsequently decanted gave as satisfactory an analytical record as the average of pure spring waters. See analysis 11.

The water sent for comparison with the results of the Hyatt filtration process gave on first examination a much better record than is generally obtained from the turbid waters of Wolf river. .011 of organic ammonia as compared with .035, .037 and 071 in analyses 26, 24 and 23 respectively. This, however, was due to an unusual accidental circumstance, the absence of any notable flakes of organic matter in the clay and other mineral particles of the quantity used in the laboratory experiments, for re-examination on the following day, gave the ordinary high results. (See analysis 14.) Waters which contain much suspended mineral matters, with comparatively few particles of organic matter, will rarely give the same results on repeated examinations, as similarity of result depends upon the presence of precisely similar quantities of organic matter disseminated in the equal measures of water used in the experiments, a condition that can seldom be established in practice; there is, however, rarely such a difference in the results as that accidentally obtained in this instance. The quantity of solid matter in this natural water amounted to 146 parts, of which 9 were destroyed by ignition, in 100,000 parts of the water as compared with 14 parts, of which 2 were destroyed, in the filtered specimen. There was removed, therefore, from every gallon of this sample of the Wolf river water by the process of filtration 77 grains of suspended matters, of which 73 consisted chiefly of fine particles of clay and other mineral substances and 4 of vegetable detritus, washed from the water shed of the stream. To clear this water the Hyatt filter would have to remove the enormous quantity of 27,500 pounds of filter-choking clay from the 2,500,000 gallons assumed to be the daily work of one of the 30-feet cylinders. This specimen, however, probably exaggerates the turbidity of the stream, for in November, 1879, when its waters were red and densely opaque after heavy rains, the total solids amounted only to 44 parts per 100,000, and the suspended matters, deducting 14 per 100,000

for saline and other matters in solution, to only 30 parts equaling 17.5 grains per gallon, or 6250 pounds for the daily work of the cylinder.

The water filtered by the Hyatt process gave satisfactory results as far as concerns the organic ammonia, although it did not equal in purity that which had been stored since November of last year; but there was present an amount of free ammonia that would have thrown suspicion on the quality of the water had its history been unknown. This free ammonia was probably taken up from the filtering materials. On a former occasion the writer met with an instance in which a water known to contain no free ammonia had its character wholly changed by its passage through a filter containing charcoal. A continuance of the filtering process would, of course, have speedily washed out this ammonia and given a water without suspicion in this respect.

From these examinations it appears that the water of Wolf river, though extremely unsightly and repulsive in its turbid state, is an excellent water when its suspended matters have been removed. In contains only about eight grains of dissolved saline substances per gallon, and the organic ammonia distilled from it falls within the arbitrary limits of wholesomeness adopted by most sanitary authorities. The removal of the suspended matters may be effected by sedimentation or filtration, but both of these processes are accomplished with difficulty by the ordinary methods. The fine-clay particles take a long time to settle, and they speedily fill up the pores of a filter and necessitate a reversal of the current. There are no facts before the writer to warrant him in forming an opinion on the ability of the Hyatt filter to accomplish its proposed work; but if the filtration be effected and a clear water furnished, that clear water will be of a satisfactory quality for all the purposes of a municipal supply.

This was demonstrated not only by the present analysis, but by several made in 1879. Wolf river water stored in the cisterns of the Peabody House in August, when the river was low and comparatively free from turbidity, and drawn and examined in November, proved a clear and colorless water of

unusual organic purity; from the cisterns of Gaston's Hotel a similar water was obtained; a cistern at 177 Union street, in which the river water had been stored for six weeks, gave a water similar in its organic constitution to that yielded by the Hyatt filter; and lastly, the river water, filtered through animal charcoal, became an organically pure supply. (See analyses 19, 22). The inference drawn from these analyses seven years ago, was that the Wolf river water, a most impure water in its natural condition, was nevertheless susceptible of purification; but it was claimed that what might be accomplished on the small scale by sedimentation in cisterns or domestic filtration would be effected with difficulty on the wholesale scale on account of the character of the suspended particles. If the Hyatt filter can accomplish the filtration, so far as the demands of quantity are concerned, the writer is confident that the filtered water, if clear, will be of satisfactory purity. This has reference to the Hyatt method of filtration only as connected with the Wolf river water. What its influence might be on a water in which the organic matter is chiefly in a state of solution and not in suspension among the inorganic particles, as in the Wolf river supply at the Louisville and Nashville Railway crossing, is unknown and does not come within the scope of the present inquiry.

Besides removing the suspended matters and yielding a clear water for domestic and manufacturing purposes, the filtration may be confidently expected to free the water from all suspicion of malarial contamination; for, as has been stated above, a thorough filtration, although incompetent to effect the removal of the typhoid poison from a water, is followed by a speedy decrease in the prevalence of malarial affections among those who use the filtered instead of the surface supply.

The propagation of typhoid fever by a water supply, depends, as already indicated, on the inflow of an infected sewage. Small streams are obviously better than large streams as a source of supply because the area drained by them may be more effectually guarded against dangerous contaminations. An efficient supervision is the only known preventive

of the invasion of typhoid by the water supply. With such care exercised over the radicles and course of the Wolf river, and the subsequent filtration of the water, as proposed, a pure and healthful supply may be obtained for the city of Memphis.

In concluding, the writer quotes from a paper on "Wholesome Water for Cities and Towns," read in May last at Philadelphia before the sanitary convention, called by the State Board of Health of Pennsylvania:

"Under the conditions of our modern civilization it seems impossible to bring the spring water in its pristine purity to our homes; but it is only a question of money and an intelligent and watchful superintendence to have a water which will be its equal in wholesomeness. Animal matter, with its typhoid possibilities, must be excluded by the selection of a suitable source, the area of which must be afterwards protected to the full. But the most careful surveillance will fail to exclude the malarial possibilities associated with the vegetable matter of an otherwise healthful surface. To remove these, nature's process of filtration must be imitated. Thus only will a water be obtained free from the danger of typhoid fever on the one hand, and of malarial diseases on the other —a pure, clear and wholesome supply, which, by preserving the community from unnecessary sickness, will, in a short time, amply repay the expenditure involved in its introduction."

CHAS. SMART,
Surgeon and Major U. S. A.

ANALYSES OF WATERS.

Figures represent parts per 100,000 of the water.

	WATER EXAMINED	Total solids	Loss on ignition	AMMONIA		Oxygen required for oxidizable matters	Nitrous Acid	Nitric Acid	Chlorine
				Free	Organic				
1	Mississippi water above Memphis, May 4, 1880	—	—	.090	.083	.630	none	.259	.40
2	Mississippi water above Memphis, taken 10 feet below surface, July 21, 1880	—	—	.028	.028	.400	none	.074	.50
3	Mississippi water above Memphis, taken 20 feet below surface, July 21, 1880	—	—	.026	.032	.350	none	.100	.50
4	Mississippi water, taken 26 miles below Memphis, May 4, 1880	—	—	.034	.027	.545	none	.194	.40
5	Mississippi above Memphis, 25 ft. below surface, Dec. 15, 1879; sedimented 3 days	20.0	6.0	.002	.036	.465	none	none	.35
6	Mississippi above Memphis, 30 ft. below surface, Nov. 18, 1879	28.0	7.0	.003	.017	.321	none	none	1.00
7	Mississippi above Memphis, 30 ft. below surface, Dec. 2, 1879; sedimented 3 days	20.0	4.5	.001	.013	.374	none	none	.50
8	Mississippi at mouth Horn Lake Pass; collected Jan., 1886; examined April, 1886	21.0	7.0	.020	.024	.225	none	trace	.90
9	Horn Lake Pass; collected February, 1886; examined April, 1886	17.0	2.0	.004	.0095	.225	none	trace	.70
10	South Horn Lake; collected February, 1886; examined April, 1886	19.0	5.0	.000	.0075	.200	none	trace	.70
11	Wolf river at L.&N.R.R. crossing; taken Nov., 1885; stored 9 months; examined August, 1886	—	—	.000	.0045	.190	none	.062	.50
12	Wolf river at L.&N.R.R. crossing; taken Aug. 11, '86, and filtered thro' a stone filter	—	—	.010	.030	.680	trace	.105	.80
13	Wolf river at L.&N.R.R. crossing; taken Sept. 16, 1886; examined Oct. 4 and 5, without previous treatment	146.0	9.0	.002	.011	—	none	.074	.20
14	Same as last; experiment repeated Oct. 6	—	—	.002	.046	—	—	—	—
15	Wolf river at L.&N.R.R. crossing, taken Sept. 16; filtered in New York Sept. 25 by Hyatt process, and examined Oct. 4 and 5	14.0	2.0	.018	.0085	—	—	.074	.20
16	Same as last; experiment repeated Oct. 6	—	—	.020	.0085	—	—	—	—
17	Wolf river from mid-stream at Raleigh, Dec. 2, 1879; sedimented 3 days	32.5	6.5	.003	.020	.447	none	none	.15
18	Wolf river at intake of Memphis Water Works, Dec. 3, 1879; sedimented 3 days	36.5	6.5	.001	.028	.459	none	none	.15
19	Wolf river water from Peabody House cisterns, stored Aug., 1879; drawn and examined in Nov.	28.5	4.5	.001	.004	.044	none	none	.45
20	Wolf river water stored in Gaston's Hotel cisterns; examined Nov. 1879	12.5	2.5	.0004	.003	.107	none	none	.20
21	Wolf river water from cistern 177 Union street, stored Oct., 1879; examined six weeks afterward	12.5	3.0	.0006	.008	.170	none	none	.80
22	Wolf river water, filtered through animal charcoal, Nov. 1879	26.0	7.0	.0004	.0015	.019	none	none	.20
23	Wolf river at mouth of stream after heavy rains, Nov. 18, 1879	44.0	6.5	.022	.071	.578	none	none	.45
24	Wolf river water as supplied to Memphis, Nov. 12, 1879	49.7	6.5	.001	.037	.301	none	none	.20
25	Wolf river water, Memphis supply Dec. 1879, when high water in the Mississippi caused stagnature at the intake; sedimented 3 days	30.0	5.0	.001	.035	.563	none	none	.20

CHAS. SMART, *Surgeon and Major U. S. A.*

[B]

MR. A. A. WILLSON'S REPORT.

NEW YORK, October 25, 1886.

General Colton Greene, Memphis, Tenn.:

GENERAL—In accordance with your request on the part of the Water Committee, I have examined the plans and specifications submitted by theNewark Filtering Company for a proposed filter-plant for the city of Memphis, and would now respectfully offer my report.

Enclosed herewith are copies of the drawing furnished me, of which A is a general plan of the arrangement of the filters; B is a vertical section of one filter showing the internal arrangement of pipes, valves, etc.; C is a plan of the same, and D is a drawing of the Cone Valve. Enclosed, also, is a copy of the specifications submitted, together with a written description of the filters and appurtenances, and an explanation of their operation, both in filtering and in washing the filtering material.

It will be seen from the plan A, that the force main, with the exception of the two branches leading to and from the filters, is entirely independent of them, and should it be necessary, may at any time, be made to deliver the water directly into the reservoir. Provision is also made at the extremity of the filter connections, at e, for the addition of another filter, should an increased water supply necessitate it.

The enclosed written description of these filters, together with the specifications, render their construction and operation so plain that I will not attempt to enlarge upon them, any further than to explain that in washing the filtering material, unfiltered water from the force main will be used, instead of the filtered water from the reservoir, as formerly contemplated. This will obviate the necessity of auxiliary pumps and boilers for this purpose, as well as the expense of their maintenance. Of course, to raise the head of water in

the stand pipe without auxiliary pumps sufficiently to wash the filter beds, will bring an increased load upon the pumping engines while the washing is being done, but in my estimation, the expense of this will be but a very small proportion of the entire cost of independent pumps and machinery for this purpose.

As far as I can now see, both the general design and arrangement of the details of this proposed filter-plant, are excellent, and I can see no reason why, in a mechanical point of view, the whole plant should not operate practically, as it is contemplated it will. Whether or no, as a filter, it will prove a success, must, in the absence of practical examples of this magnitude, rest with the prediction of the civil engineer, until its entire success, on so large a scale, is established by precedent.

The strength of the boiler plates composing the filters as specified, is abundantly adequate. The diameters of the water pipes and valves are all properly proportioned, but the thickness of the iron of the pipes not being specified, may be determined by your superintending engineer, should the work proceed. It is also highly probable that improvements in the minor details may hereafter be made, which will meet with his approval. It is proposed by the Filter Company to operate the small pumps, for feeding the coagulant, by means of a wheel placed in the inlet pipe to the filter. If this device is properly designed and constructed, it will prove an excellent plan, as any change in the velocity of the water flowing through the pipes, will vary the speed of the wheel, and the quantity of coagulant forced into the inlet pipe will in consequence, be proportioned to the quantity of water flowing to the filters.

The device proposed for aerating the water after its filtration, is both novel and ingenious. This consists of a well, five feet in diameter and one hundred feet deep below the level of the water in the reservoir, the water standing in it at the same height as that in the reservoir. In the center of this well, and extending down to, say within a foot of the bottom, is a thirty inch pipe reaching nearly up to an elbow

on the outlet pipe from the filters. Between the upper end of this pipe and the elbow on outlet pipe, are placed a number of open-ended cones made of thin sheet brass or copper, and set one within the other, about one sixty-fourth of an inch apart. The water flowing down this pipe from the filters, will, by its velocity, draw in air through these cones, which, when it reaches the bottom of the well with the descending water, will, by the pressure exerted by the head of water above it, be absorbed by the water, and be carried into the reservoir with it. The fact that air will be drawn down a tube by a descending current of water, was established nearly a half century ago, the air for blast furnaces being furnished by such device; hence, I can see no reason why, if properly designed, it should not be in this case entirely successful.

I would recommend that all the valves in connection with the filters, be fitted with outside screws. Those shown upon the drawings have the screws inside, which upon being exposed to the muddy water and frequently operated, would soon wear out and need renewing. The valves might be operated by means of hydraulic cylinders, should a plan be submitted to your superintending engineer that would meet his approval.

While filtering, it is expected that the height of water in the filters will be, say fifteen feet above the bottom of the filters. According to the plan, it is contemplated that the bottom of the filters will be placed six feet above the average level of the water in the reservoir, in order to give sufficient head to operate the Aerator, which added to the fifteen feet in the filters, would make twenty-one feet additional static head against the pumping engines while filtering, for a period of twenty-three hours per day.

It is contemplated that one hour in each twenty-four will be occupied in washing the filtering material, at which time an additional head of say twenty-five feet will be required, making an additional average head for the twenty-four hours, of twenty-two feet, to which if we add say two feet for friction of water through the inlet pipes, will make a total addi-

tional dynamic head against the pumping engines, due to filtering, of twenty-four feet. Having no profile of the proposed line of the force main, which if I understand rightly will be thirty inches diameter and nine miles long, it will be impossible to compute accurately just how much head of water it will require to overcome the frictional resistance, and force seven and one-half million gallons of water through it in twenty-four hours; but from the results of some observations taken from a thirty-inch force main, having probably the same proportionate number of bends as the one proposed for Memphis, I estimate this required head to be forty-six feet, which added to one hundred feet static head, gives a total dynamic head against the pumping engines, when not filtering but pumping directly into the reservoir, of one hundred and forty-six feet. Now, while filtering, this head will be increased twenty-four feet, as shown above, making a total dynamic head against the pumps, of one hundred and seventy feet, or sixteen and forty-four hundredths per cent. more head than when not filtering. Assuming the yearly average duty of the pumping engines to be sixty million pounds of water raised one foot high for each one hundred pounds of coal consumed in actual pumping, then to raise seven million five hundred thousand gallons, or sixty-two million four hundred and seventy-five thousand pounds of water, one hundred and forty-six feet high in twenty-four hours, will require a fraction over seven and six-tenths tons of coal, of two thousand pounds each, per day. In filtering, the increased head to be maintained as shown above will require, estimating the efficiency of the pumping machinery at eighty-two per cent., an increased consumption of fuel of thirteen and one-half per cent., or in round numbers, one ton of coal per day when filtering at the rate of seven and one-half million gallons in twenty-four hours.

Now, a portion of this water pumped, but not filtered, must be wasted in washing the filtering bed. In their specifications the Filter Company assume that this quantity will be about two per cent. of the whole amount pumped, but in the absence of reliable data regarding this washing operation on so large

a scale, I am disposed to increase this proportion to at least three per cent., which I think will be more reliable for a safe estimate of cost. From various reports of the performance and cost of operating pumping works, it is safe to assume that in the case of the proposed works for Memphis it will cost, including coal and all operating expenses and repairs to machinery, six and one-half cents to raise one million gallons of water one foot high, of which amount about seventy per cent. will be for fuel and the remaining thirty per cent. for operating and other expenses. In my former computations of the cost of filtering, I have provided for the cost of the coal to raise this water for washing, hence I can now add only the expense of operating the works while pumping the water for washing. As shown above this will be thirty per cent. of the whole cost or one and ninety-five hundredths cents for each one million gallons raised one foot high. Hence, three per cent. of seven and one-half millions is twenty-two and one-half per cent. of one million, which multiplied by one and ninety-five one hundredths cents multiplied by one hundred and seventy feet, gives in round numbers seventy-four and fifty-eight hundredths—say seventy-five cents per day, as the cost of the water used in washing the filters.

It is my opinion that to operate and wash these filters properly, the services of two men will be required, the aggregate pay of which would be one thousand dollars per year. One of these men, however, might be otherwise employed when not washing the filters.

While pumping the water for washing the filtering material, the pumping machinery will have to pump under a head of one hundred and ninety-five feet, and will in consequence have to be of sufficient strength for this work, although pumping at a reduced rate of capacity. The additional cost of this can only be determined upon opening the proposals submitted by the builders of the machinery.

Mr. Hyatt's estimate of the cost of renewing the filtering material washed out in washing the filters, also in renewing the coke, is about fifty dollars per year. The cost of coagulant at one dollar per million gallons would be seven dollars

and one-half per day. To all of these expenses must be added the interest on the cost of the filters and foundations—say one hundred thousand dollars at six per cent. or six thousand dollars per year.

Considering the limited demonstration the Filter Company have only been able to make of the practical working of this filter, it is impossible for the Engineer to predict with certainty its success, or its failure, when adopted for works of as large capacity as those proposed for Memphis; but in view of the ingenuity displayed by the inventor, as well as the energetic character he has thus far shown in bringing this invention to its present stage of perfection, I can see no reason why, should this filter be adopted at the Memphis Water Works, it would not prove an entire success.

I would therefore recommend that the Water Committee adopt this plan of filtration, should its expense not exceed the limit of authorized expenditure.

Respectfully submitted.

A. A. WILLSON,

Mechanical Engineer Quintard Iron Works, N. Y. City.

[C]

MR. J. J. R. CROES' REPORT.

NEW YORK, November 20, 1886.

Gen. Colton Greene, of the Memphis Water Committee:

SIR—I have examined at your request the plans and method of operation of the plant proposed by the Newark Filtering Company for filtering the water of Wolf river for a supply to the city of Memphis.

This plant consists of three cylindrical tanks, each containing a filter bed of sand and coke, six feet deep, and having fourteen feet of water space above the filtering material. The arrangements for feeding and drawing off the water and for washing the filter bed, are fully described in the specifications and plans submitted by the company.

The mechanical arrangements for operating the filter are ingenious and effective. In some details I think improvement might be made in the direction of convenience of operation, but these are not essential parts of the scheme.

The area of filtering surface in the three tanks is 2150 square feet, and it is proposed to pass through the filters 7,500,000 gallons a day.

The time occupied in washing the filter bed is assumed to be one hour a day, leaving twenty-three hours for filtering.

This rate of filtration will require the passage of the water through the sand at the rate of about 152 gallons per hour per square foot of filter surface.

I believe the maintenance of this rate of filtration for twenty-three hours to be impossible under the conditions. Such experiments on the rate of percolation of water through sand, as I have been able to find recorded, lead me to believe that with a head of fourteen feet it is possible to pass clear water through six feet of sand at a somewhat greater speed than that proposed in this case, for a short time, but the invariable rule is that the rate of percolation decreases rapidly

in consequence of the compacting of the whole mass and particularly of the finer upper strata.

Where the water filtered is turbid, the rate of percolation diminishes more rapidly, from the deposit of the suspended matter in the interstices of the filtering material. With the Wolf river water, this will occur to a very great extent in your works, and I am of the opinion that to fulfill the requirements of the guarantee, it will be necessary to so arrange the tanks that a head of at least fifty feet can be put on the filter. This opinion is confirmed by tests which I have made of the operation of one of the largest plants which the Newark Filtering Company have built—that of the Norfolk and New Brunswick Hosiery Company, at New Brunswick, N. J. Lack of time has prevented making as thorough an examination of this subject as is desirable, but no doubt exists in my mind that the proposed rate will be found impracticable under the proposed conditions.

The operation of the proposed Memphis Filter, is entirely different from that of a closed filter placed between a pump and the lower end of a force main or a stand pipe, where the back pressure tends to stir up the filtering material from the bottom and make it always open and pervious. In your case there will be no back pressure, and the tendency of the water will always be to compact and consolidate the upper strata of the filter and make it less pervious.

The purification of water by filtration, at the proposed rate of percolation, is, I believe, unexampled prior to Mr. Hyatt's ingenious use of a coagulant introduced into the water just before its passing on to the filter bed. This appears to have increased the capacity of filtration of a given area, to about seventy-five times what is possible by a simple filtration. The practicability of the method is, I think, fully proven.

The aeration of the filtered water is essential to its remaining pure in the reservoir. The proposed method of charging the water with air, is ingenious and likely to prove efficacious.

There is some doubt as to whether the duration of the period of intimate contact between the air and the water under high pressure will be sufficient in passing through 100 feet of

pipe, to produce the oxidation necessary to preserve the water pure for any length of time. The combined air and water will be under pressure of over 20 lbs. for only a few seconds. The process of absorption of oxygen from the air by the water is a slow one, and the very brief time of close contact under pressure will probably not do as much good as is anticipated, although it will unquestionably be of some benefit.

The method of washing the filter beds is novel and ingenious. The washing from below in sections of one-quarter of the area at a time, appeared to me on examining its operation, to be exceedingly effective and to have the great advantage of causing the filtering material to be deposited when the washing ceased, in perfect gradation, as regards its specific gravity, the coarser pebbles falling to the bottom and the finest particles remaining at the surface where they are wanted.

It is open to the objection that a certain proportion of the mud and deposit washed out, will remain in the filter and be deposited on the surface of the unwashed segments. But this will probably be so small as not to seriously interfere with the filtration. I agree with Mr. Willson in the opinion that the quantity of water required for washing the filter beds will be considerably in excess of two per cent. of the amount filtered.

The computations of Mr. Willson of the cost of pumping the water are based on the supposition that the average level of the water will be nine feet over the filter beds or 21 feet above the reservoir.

As above stated, I think that the average head to be pumped against will be 50 feet above the filter beds or 62 feet above the reservoir. This would increase the annual cost of pumping about $2700 above Mr. Willson's estimates, and would make the annual cost of the filtering, including all expenses and interest on cost about $13,850, which is equivalent to 50 cents per million gallons filtered.

The cost of filter beds, such as those in Poughkeepsie and Hudson and English towns, would be about $250,000, and the cost of maintenance $1.50 per million gallons filtered, a

total of about $2 per million gallons, or four times as much as the greatest estimated cost of the proposed works.

In conclusion, I am of the opinion, that the general plan of filtration proposed, is entirely practicable and will be economical, and I recommend its adoption. The particular plant described in the specifications, I consider insufficient to accomplish the desired end, only in respect to the head of water provided for on the filter beds, which should be greatly increased. The auxiliary stand pipe also appears to me to be too small for the object sought to be attained by it.

Respectfully submitted.

J. J. R. CROES,
Civil Engineer.

[D]

DESCRIPTION OF OPERATING THE PLANT FOR PURIFYING THE WATER FOR CITY OF MEMPHIS, TENN.

Submitted by the Newark Filtering Company.

FILTERING.—

The water from the force Main enters the main Inlet pipe B, and passes through Turbine wheel E. (The said Turbine wheel communicates motion to the Pumps, which will feed a definite quantity of coagulant into the water continually, both while filtering the water and while washing the filtering material. The coagulant is fed into the water after it leaves the Turbine wheel.) The water then flowing through the Inlet pipes to Filters, enters the Filter above the filtering material, down through which it percolates, passing through the Cone valve outlet system and Outlet pipe, from each Filter, enters the Main Outlet pipe, which conducts the water to the Aerating apparatus, through which the water passing, flows down through a pipe to bottom of *Well*, 5 ft. diam. 100 ft. deep; it then returns to top of *Well*, and is conducted through pipes into the force Main from Pumps to Reservoir, and thence into the Reservoir.

Valves are placed in Main Inlet and Outlet pipes to and from filters, also in force Main from Pumps to Reservoir, between its connection with the two above mentioned pipes.

The object of above valves is to enable the Plant to be disconnected without disturbing the force Main or the flow of the water through it.

DESCRIPTION OF PIPES AND VALVES FOR EACH MACHINE.—

The 16-inch Waste pipe and the 14-inch Inlet pipe are both connected with the Outlet pipe by means of a 14-inch pipe, which has a Gate valve placed in each pipe, as per drawing. Gate valves are also placed in both 16-inch Waste pipe and 14-inch Inlet pipe, between where they connect with above

14-inch pipes and with the 16-inch pipe, which serves as the Inlet pipe while filtering the water, and the Waste pipe while washing the filtering material.

The 14-inch Outlet pipe is divided into four 7-inch branches, which connect with the Outlet system of each quadrant. In each of the 7-inch pipes Gate valves are placed, as indicated in drawing. While filtering, the four 7-inch valves are open, also the valves in the 14-inch Outlet pipes and in the 14-inch Inlet pipes; all other valves are closed. As before stated, the water then enters the Filter above the filtering material, (through the above-mentioned 16-inch pipe), percolates down through filter bed into Cone Outlet valves, thence through the Outlet system and the four 7-inch pipes into the 14-inch Outlet pipe.

Before washing the filtering material the attendant in charge of Filters should signal engineer at pumping station to slow pumps sufficiently to allow the level of the water in the machines to fall even with wrought iron channel, built around 8-ft. cylinder. When the level of the water has fallen as above specified, the valve in the Waste pipe should be opened and the valves in both the Inlet and 14-inch Outlet pipes closed; the valves in three of the four 7-inch Outlet pipes should also be closed; and the valve in the 14-inch pipe connecting the Inlet and Outlet pipes opened. The water will then pass from the Inlet to the Outlet pipe, thence through one of the 7-inch pipes and Outlet system connected with same.

After repeating above operation with each of the other two machines, the engineer should be signalled to increase to about ten pounds above working pressure of the pumps. The water, then flowing through the Cone Outlet valves, enters the Filter beneath the filter bed, up through which it passes, agitating, loosening and cleansing one-quarter of the filtering material of each Filter. The water overflows into wrought iron channel, carrying with it the silt. The waste water escapes from channel into Waste pipe and thence into drain. When one-quarter of filtering material has been sufficiently washed, open another one of the 7-inch Gate valves and clear the one previously open. Continue this operation with each machine

until the entire filter bed of each Filter has been thoroughly cleansed, then close valve in pipe connecting Inlet and Outlet pipe; also valve in Waste pipe, and open the valve in pipe connecting Outlet and Waste pipes; also the four 7-inch Outlet valves in each Filter; then open the valve in Inlet pipe. The water enters the Filter above filtering material, percolates down through the same, thence through Outlet system, Outlet pipes and pipe connecting Outlet with Waste pipe into the Waste pipe.

The water from the Filters, after washing, should be allowed to run to waste for a few minutes in the manner just described, as it will not have been perfectly filtered, the interstices of filter bed being filled with unfiltered water when the machine is first started filtering the water. After the water has run to waste for a few minutes, the 14-inch Outlet valves should be opened and the valves in pipes connecting Outlet and Waste pipes closed; the water will then pass into Main Outlet pipe, thence through Aerating apparatus and Well into Reservoir.

In place of stopping pumps, before washing machines, it is thought best to provide a Stand Pipe, as indicated on drawing, the said Stand Pipe to be of sufficient height to give necessary head for washing Filters. If while operating the valves pressure should be suddenly increased, the surplus water would simply run to waste through a pipe which connects the top of Stand Pipe with drain.

It will require, for cleansing the material, about two per cent. of the entire quantity of water pumped.

The time occupied in the washing process will be about one hour.

[E]

SPECIFICATIONS.

Plant for Filtering and Aerating the Water for the City of Memphis, Tenn.

Plant.—

The plant to consist of three Filters 31½ ft. diam. and 20 ft. high, for filtering the water.

A Well 5 ft. diam. 100 ft. deep, for aerating the water, after it has been filtered.

A Stand Pipe 30 ft. diam. to regulate the head under which the filters are to be washed. The said Stand Pipe will do away with necessity of stopping pumps, while operating valves, for washing filtering material.

Apparatus for feeding Coagulant into the water, before the water enters the filters.

A small suitable building for the attendant, or person who takes care of the machines.

Location.—

The above Plant to be located alongside of distributing reservoir.

Capacity.—

The above Plant will purify constantly 7,500,000 gallons per day of twenty-four hours.

Washing Filters.—

About 2 per cent. of water pumped, each day, will be required for cleansing filter bed.

During the interval of washing machines, an extra pressure of about 10 lbs. will be required upon the pumps.

Foundation for Filters.—

Foundation to be built of sufficient height to give required head. A Central Cylinder under each machine, and passage leading thereto to be masonry; the said central cylinder and passage is to enable the valves to be readily reached and operated.

The above foundation, to be built in the best manner to support weight of Plant. The weight of each filter and contents, will be about 506 tons.

The filters to be built upon above foundation, and the bottom of each machine to be laid in cement.

The bottom of filters over passage leading to Central Cylinder is to be supported by means of channel iron, as shown on drawing.

CONSTRUCTION.—

Filters are to be built as per drawing, and in the following manner:

Each will be 31½ ft. in diam., and have a central cylinder 8 ft. diameter for operating valves; the height of filters will be 20 ft. The cylinders to be built of wrought iron ⅜ in. thick, and are to be double riveted.

The bottom, which will also be of wrought iron ⅜ in. thick, is to be flanged to fit cylinders, and is to be riveted thereto and caulked, as indicated on drawing. Around outside of 8 ft. cylinder, 9 ft. 5 in. from bottom of filter, a channel is to be built of wrought iron ¼ in. thick.

This channel is to conduct the waste water to the waste pipe while washing the filtering material.

The cylinder is to be strengthened at the top by means of a 2-in. angle iron, which is to be riveted around inside of large cylinder.

A roof or covering is to be built over each machine, the said roof to be supported and fastened to outside cylinder.

The above roof to have necessary sky-lights for light and ventilation.

In central cylinder, near the bottom, a platform is to be built; from this platform the five outlet valves are to be operated.

From passage in foundation to above platform, and also from platform to top of 8 ft. cylinder, where a second platform is to be constructed, suitable stairs are to be erected.

OUTLET SYSTEM.—

There are to be 420 cone outlet valves in each filter; these are to be connected in such a manner as to permit one-quarter of filtering material to be washed at one time.

The 7-in. pipe of the outlet system of each quadrant (on the inside of filter) is to be bolted to cast iron flange, which is riveted on inside of 8 ft. central cylinder as per drawing.

EXTERNAL PIPING.—

The four 7-in. pipes, which connect the outlet system of the four quadrants with casting in center of 8 ft. cylinder, are to be cast iron, and are to have gate valves placed in each of the four pipes, as per drawing.

A 14-in. pipe, in which a gate valve is to be located, as per drawing, is to connect the above casting in each filter with a 30-in. pipe, which connects the three filters with "Aerating Apparatus" and "Well." 14-in. pipes with gate valves, located as per drawing, are to connect the outlet pipe with the 16-in. waste pipe and the 14-in. inlet pipe. The 14-in. Inlet pipe and the 16-in. Waste pipe, with valves located in each, as per drawing, connect with a 16-in. pipe. The said 16-in. pipe is to be used as both inlet and outlet pipe, and is to be bolted to cast iron ring, which riveted on inside of 8 ft. cylinder 9 ft. 1 in. from bottom of filter to center of ring.

The 14-in. Inlet pipe connects the filter with a 30-in. pipe, the said 30-in. pipe connects the three filters with main pipe from pump to reservoir.

Connecting with above 30-in. pipe, a wrought iron Stand Pipe is to be erected, as per drawing; the said stand pipe to be 30 in. diameter, and sufficiently high to give required head for washing filtering material. A 30-in. pipe for carrying off the overflow water, connects Stand Pipe with drain.

In 30-in. Inlet pipe, between above Stand Pipe and Main, from Pumps to Reservoir, a Gate valve is to be placed. The 16-in. Waste pipe from each filter, is to be connected with drain.

FILTERING MATERIAL.—

The bed in each filter is to be 6 ft. deep, containing about 4594 cubic feet of filtering material, consisting of two parts sand and one part coke.

AERATING APPARATUS.—

The 30-in. Outlet pipe from filters is to be connected with top of aerating apparatus; also a 30-in. pipe to be connected with bottom of same.

This last mentioned pipe is to extend nearly to bottom of 5 ft. well, and is to be opened at the bottom.

The well is to be 5 ft. diam. and 100 ft. deep, and is to be built of wrought iron. The bottom of said well is to be cemented.

A 30-in. pipe connects said well with main pipe to reservoir; between well and main pipe, a gate valve is to be placed; also a gate valve in main pipe. between its connection with inlet pipe to filter and outlet pipes from well.

The above plant to be built according to drawing and above specifications, and to be connected with main as described. The material used to be of the best quality, and work to be done in a workmanlike manner.

Inside of Filters, wrought iron well and Stand Pipe to be given a heavy coat of black varnish and powdered asphaltum dusted into said varnish; thus protecting surface of iron by means of a thick and durable coat of bitumen.

The space around cone valves to be filled with cement; the said cement to be built up into pyramids between each cone valve; the base of pyramids being on a level with top of cone valves.

PAINT.—

Outside of Filters, Stand Pipe and external piping to be painted two coats of boilermakers' black varnish.

All apparatus, not especially mentioned, to be painted in a suitable and substantial manner.

[F]

SPECIFICATIONS.

Filter 31½ Ft. Diam., 20 Ft. High—Wrought Iron Work.

Filter to be built as per drawing, and in the following manner:

Filter to be 31½ ft. inside diam. and 20 ft. high; to have a central cylinder 8 ft. inside diam. and 20 ft. high.

The cylinders to be built of wrought iron ⅜ in. thick, and are to be double riveted.

The bottom, which will also be wrought iron ⅜ in. thick, is to be flanged to fit cylinders, and is to be riveted thereto and caulked, as indicated on drawing.

Around outside of 8 ft. cylinder, 9 ft. 5 in. from bottom of filter, a channel is to be constructed of wrought iron ¼ in. thick.

The said channel, diametrically opposite Inlet and Waste pipe hole, to be 20 in. wide; the width of channel to increase from this point, until in front of Inlet and Waste pipe hole, where it is to be 24 in. wide; the channel to be 20 in. deep.

The Outside cylinder to be strengthened at the top by means of 2-in. angle iron, riveted around inside of said cylinder.

The four Outlet flange castings to be riveted on inside of 8 ft. filter, 14 in. from bottom of filter to center of casting, as per drawings.

The cast iron Ring for Inlet and Waste pipe, to be riveted on inside of 8 ft. cylinder with counter-sunk rivets, in order that a seat may be made for rubber gasket, between said ring and Inlet and Waste casting.

Inside of central Cylinder, near the bottom, a platform is to be built; also, a platform at top of same cylinder; around the last mentioned platform, suitable railings are to be built.

The above two platforms are to be connected by means of suitable stairs, as indicated on drawing.

MACHINE WORK.—

The cast iron Ring for Inlet and Waste pipe casting, to have counter-sunk holes drilled for rivets; also, holes drilled and tapped for 20 $\frac{3}{4}$-in. x 2$\frac{3}{8}$ in. tap bolts.

The Inlet and Waste pipe casting to have clearance holes drilled in large flange, for 20 $\frac{3}{4}$-in. bolts; also, clearance holes drilled in small flange for 12 $\frac{3}{4}$-in. bolts. The Outlet flange castings to have holes drilled for rivets; also, holes drilled and tapped in each side of flange, for 8 $\frac{5}{8}$-in. x 2-in. tap bolts. The cast iron Offsets to have clearance holes drilled in each flange for 8 $\frac{5}{8}$-in. bolts.

CONE OUTLET VALVES.—

The Cone Outlet valves to be of size and form indicated on drawing No. 480; to have left-hand thread tapped in each valve for 1-in. pipe, as shown; to have three holes drilled and tapped for $\frac{1}{4}$-in. x $\frac{3}{4}$-in. screws; also, 4 5-16-in. holes drilled in flange.

Near the bottom of each cone valve, a disc of perforated copper (same as sample) is fastened by means of 3 $\frac{1}{4}$-in. x $\frac{3}{4}$-in. brass screws; also, another disc of the same perforated copper, to be fastened on top of cone outlet valves by means of a cast iron ring, which is bolted to valves by means of 4 $\frac{1}{4}$-in. x 1$\frac{1}{4}$-in. bolts.

The above mentioned cast iron ring to have 4 5-16-in. holes drilled for bolts.

The space between perforated disc is to be filled with 5$\frac{3}{4}$ lbs. of copper shot, (same as sample).

The perforated copper Disc and copper Shot to be furnished by us; all other parts you are to furnish and fit up, according to drawing and in a workman-like manner.

OUTLET SYSTEM.—

The 420 Cone Outlet valves to be located and connected with Outlet castings by means of iron pipes and fittings, in the manner indicated on drawing No. 799.

The space around cone valves to be filled with cement, which is to be built up into pyramids between each cone valve; the base of pyramids being on a level with top of said cone valves.

EXTERNAL PIPING.—

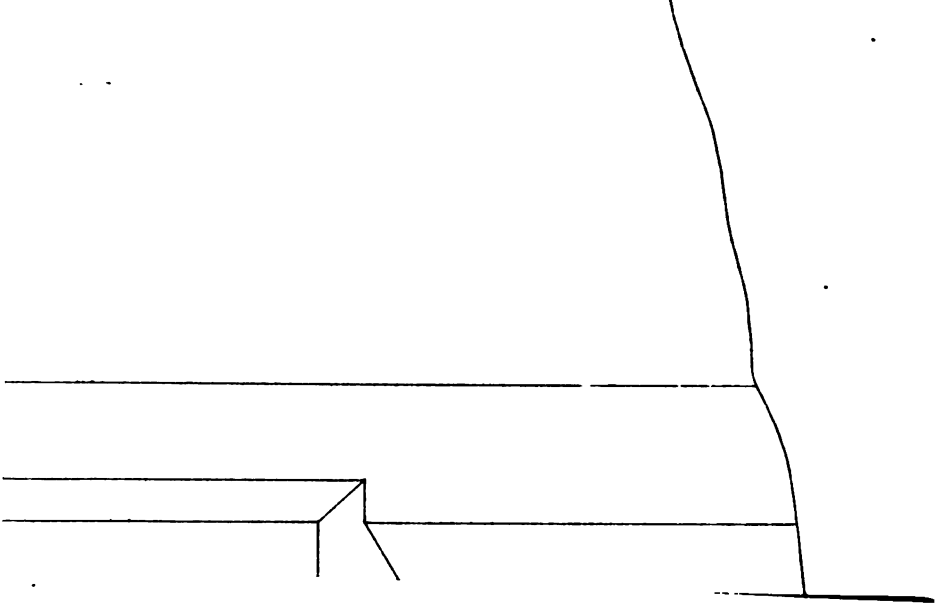
You are to furnish and connect with filter and with each other, all Pipes, Valves and Fittings, indicated on drawings. We will furnish Copper Shot and Perforated Copper (for cone Outlet valves), all other parts you are to furnish and fit up, according to drawings and above specifications.

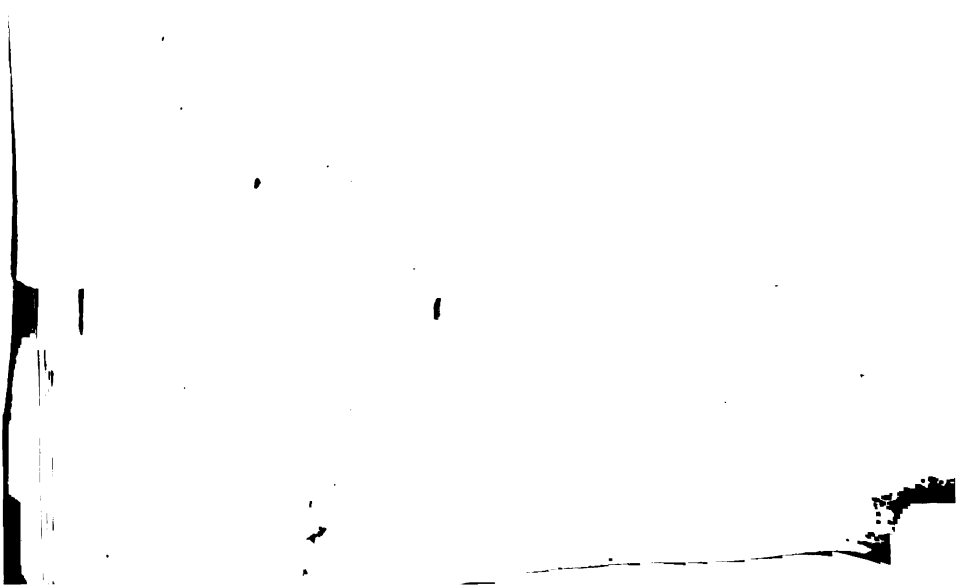
All seams and joints around castings should be caulked, and the inside of filter to be given a heavy coat of black varnish and powdered asphaltum dusted into said varnish.

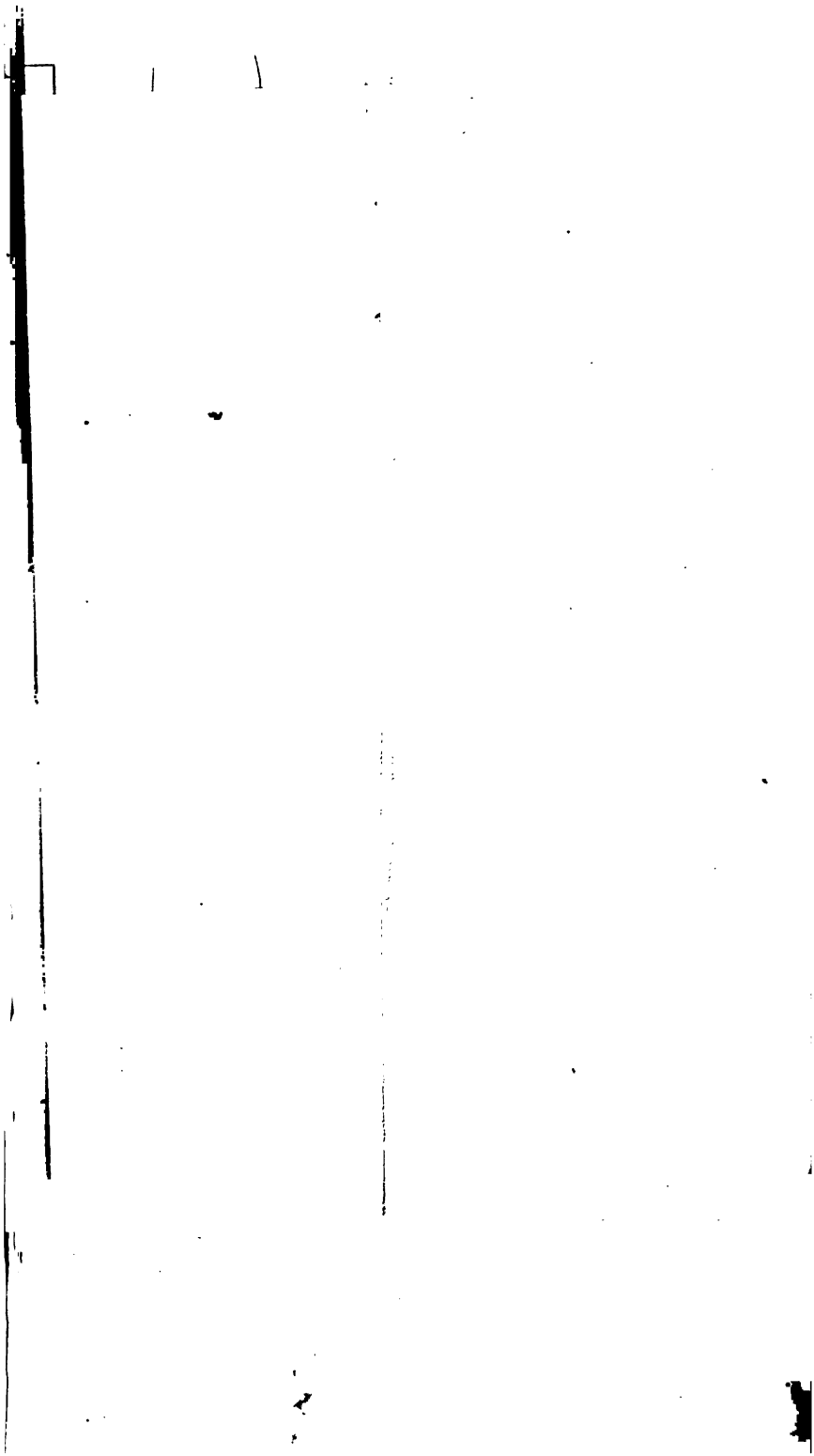
Outside of Filters and External Piping to be painted two coats of boilermakers' black varnish.

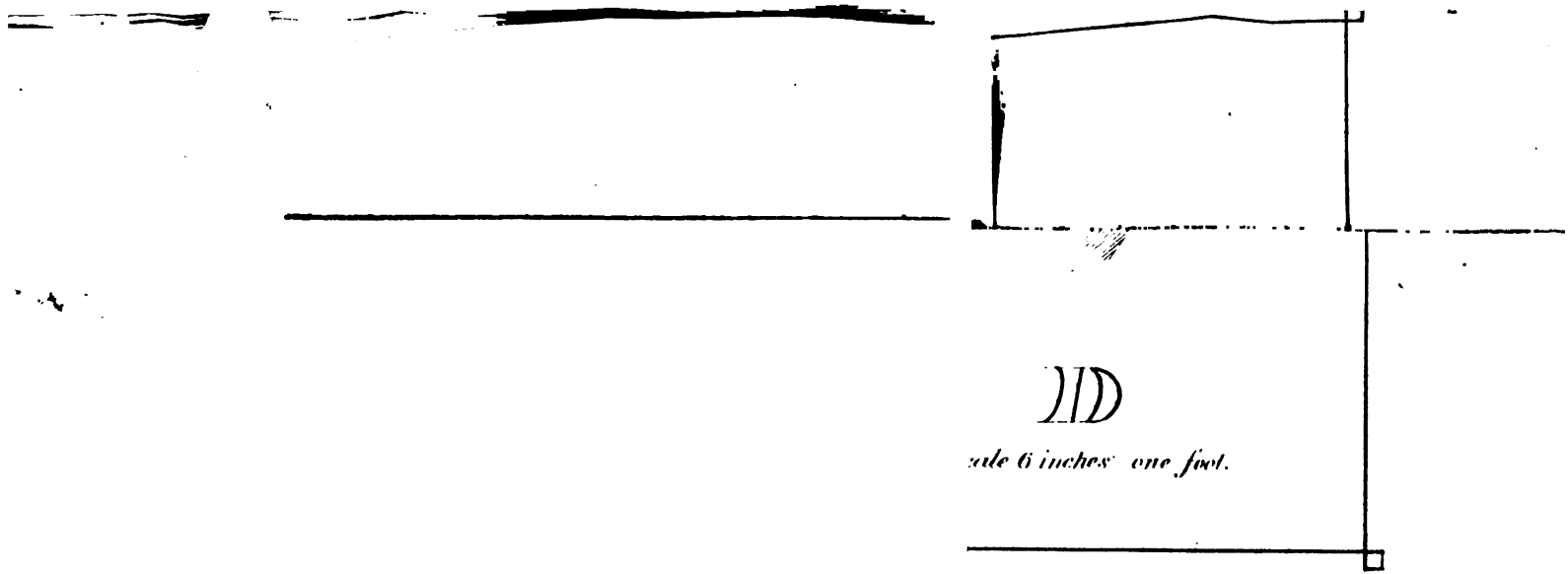
All material used to be of good quality, and filter built according to drawings, and in a workman-like manner, subject to your approval.

The accompanying drawings will give all necessary measurements, etc.









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